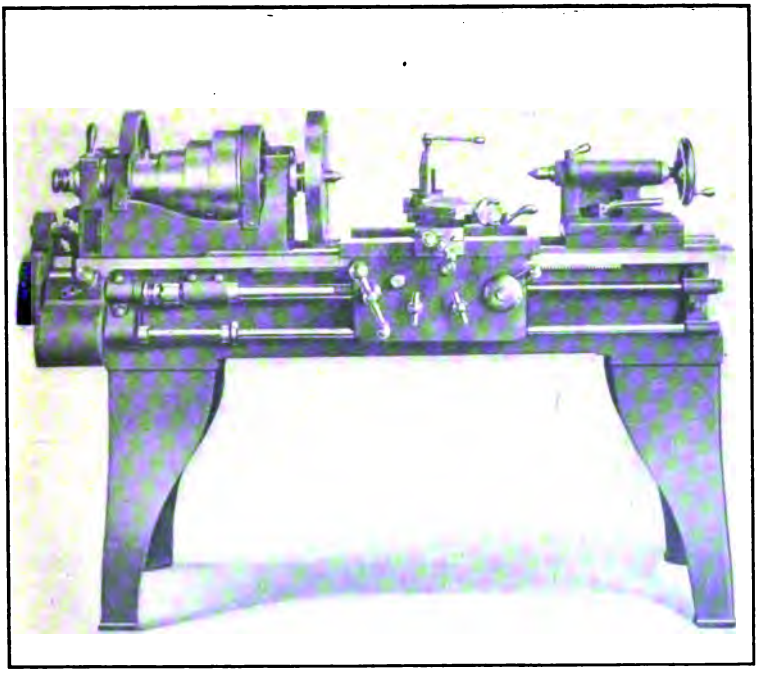
PRICE 25 CENTS

OPERATION OF MACHINE TOOLS

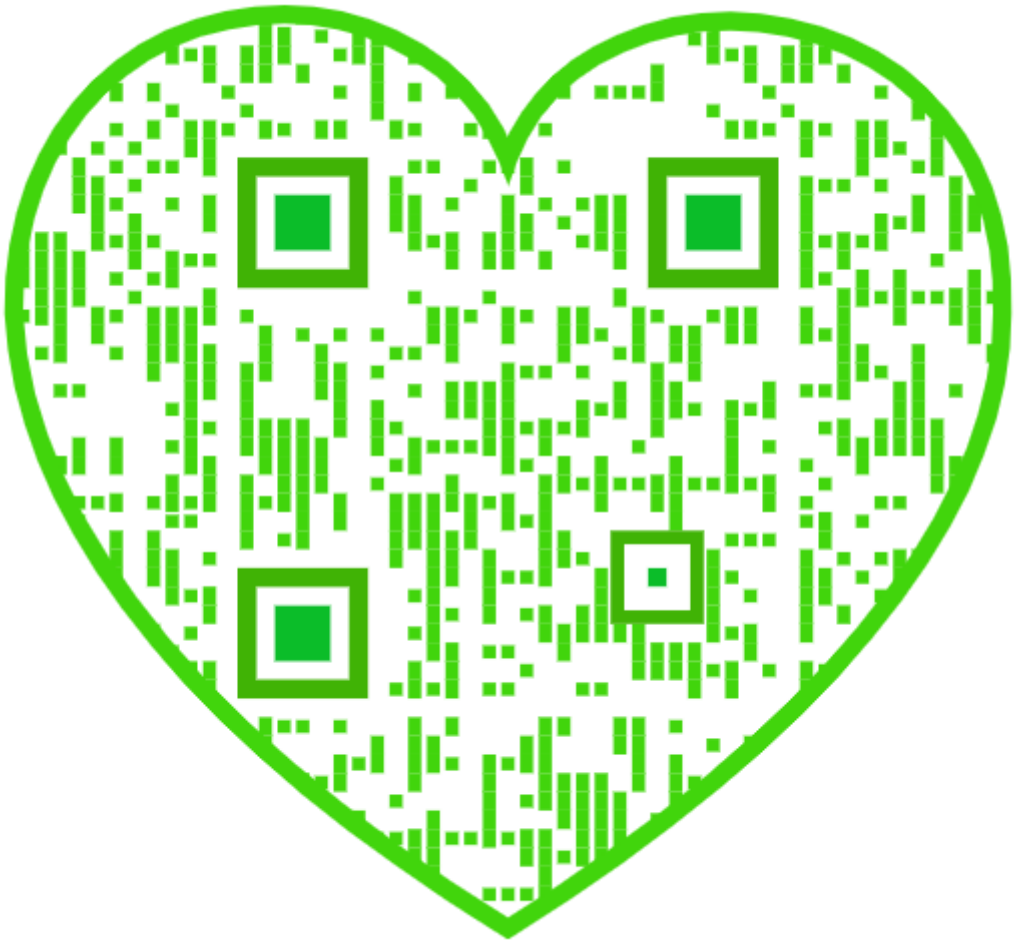
BY FRANKLIN D. JONES

THE LATHE—PART I

SECOND EDITION



MACHINERY'S REFERENCE BOOK NO. 91
PUBLISHED BY MACHINERY, NEW YORK



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NUMBER 91

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THE LATHE

PART I

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INTRODUCTION

MACHINERY'S Reference Book, No. 91, is the first of a series containing, in condensed form, information on the operation of various types of machine tools. The first two books (Nos. 91 and 92) are descriptive of lathe work, and the succeeding numbers deal with machines of other types, such as the planer, shaper, drill-press, horizontal and vertical boring machines, milling machine, and grinder. In each case, a tool of typical design has been selected, and the important points connected with its operation and use have been considered. The method of setting up a Brown & Sharpe automatic screw machine, with a detailed description of its operation, is also given in this series. In the operation or manipulation of machine tools, as well as in other branches of machine construction, there are many things which are learned more easily by experience than in any other way; in fact, it would be impossible by a written explanation to convey more than a crude idea regarding many methods connected with shop practice. Therefore, in this series, no attempt has been made to cover every phase of machine work, but we have endeavored to explain the more important features connected with the use of standard machine tools. The various methods referred to are not, in every case, given as the best from a standpoint of accuracy, nor has the time element always been considered, but an effort has been made, instead, to select simple methods and examples which would clearly illustrate the principles involved. As the variety of machine tools now in use is extensive, and as different types can often be employed for the same kind of work, it might be well, in the beginning, to call attention to the fact that the best type of tool to use for machining a given class of work frequently depends on circumstances. To illustrate, a certain part might be turned in a lathe, which could be finished in some form of automatic or semi-automatic turning machine much more quickly. It does not necessarily follow, however, that the automatic is the best machine to use; because the lathe is designed for general work and the part referred to could doubtless be turned with the regular lathe equipment, whereas the automatic machine would require special tools and it would also need to be carefully adjusted. Therefore, if only a few parts were needed, the lathe would be the best tool to use, but if a large number were required, the automatic or semi-automatic machine would probably be preferable, because the saving in time effected by the latter type would more than offset the expense for tool equipment and setting the machine. It is also necessary, in connection with some work, to consider the degree of accuracy required, as well as the rate of production, and it is because of these varying conditions that work of the same general class is often done in machines of different types, in order to secure the most efficient results. This matter has been referred to at the outset to indicate, in a general way, the principle of tool selection.

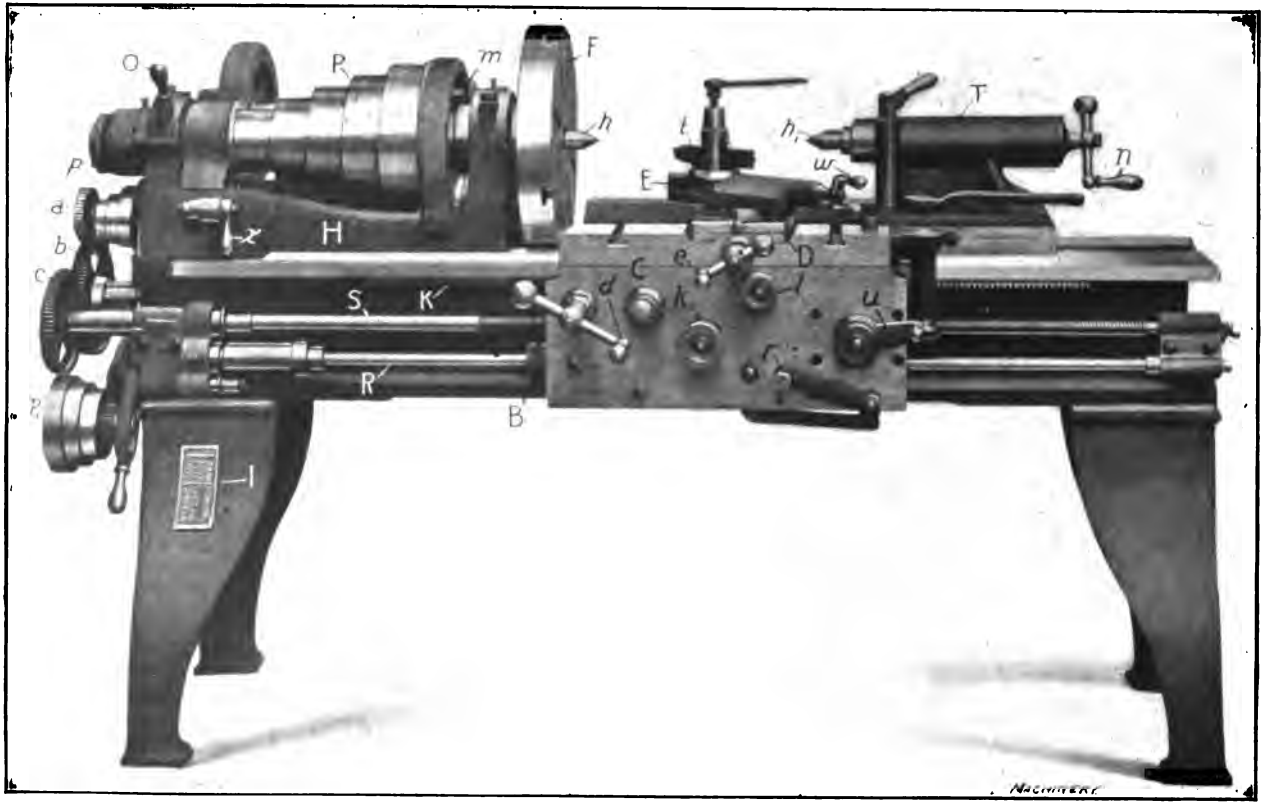


Fig. 1. Bradford Standard Lathe—View of Front or Operating Side

CHAPTER I

GENERAL DESCRIPTION OF AN ENGINE LATHE

The standard "engine" lathe, which is the type commonly used by machinists for doing general work, is one of the most important tools in a machine shop, because it is adapted to a great variety of work, such as turning all sorts of cylindrically shaped parts, boring holes, cutting threads, etc. The illustration Fig. 1 shows a lathe which, in many respects, represents a typical design, and while some of the parts are arranged differently on other makes, the general construction is practically the same as on the machine illustrated.

The principal parts are the bed *B*, the headstock *H*, the tailstock *T*, and the carriage *C*. The headstock contains a spindle which is rotated by a belt that passes over the cone-pulley *P*, and this spindle rotates the work, which is usually held between pointed or conical centers h and h_1 in the headstock and tailstock, or in a chuck screwed onto the spindle instead of the faceplate *F*. The carriage *C* can be moved lengthwise along the bed by turning handle *d*, and it can also be moved by power, the movement being transmitted from the headstock spindle either through gears *a*, *b*, *c*, and screw *S*, or by a belt operating on pulleys p and p_1, which drive the feed-rod *R*. The screw *S* is used when cutting threads, and the feed-rod *R* for ordinary turning operations; in this way the screw is worn as little as possible, and its accuracy is preserved. On the carriage, there is a cross-slide *D* which can be moved at right angles to the lathe bed by handle *e*, and on *D* there is an upper or compound slide *E* which can be swiveled to different positions. The tool *t*, that does the turning, is clamped to the upper slide, as shown, and it can be moved with relation to the work by the lengthwise movement of the carriage *C* on the bed, by moving slide *D* crosswise, and by slide *E*, which can be set to any required angle. The first two movements can be effected by power, the lengthwise feed being engaged by tightening knob *k*, and the cross-feed by tightening knob *l*. The direction of either of these movements can also be reversed by shifting lever *r*. Ordinarily the carriage and slide are adjusted by hand to bring the tool into the proper position for turning to the required diameter, and then the power feed (operating in the desired direction) is engaged. The tailstock *T* can be clamped in different positions along the bed, to suit the length of the work, and its center h_1 can be moved in or out for a short distance, when adjusting it to the work, by turning handle *n*.

As some metals are much harder than others, and as the diameter of the part that is to be turned also varies, speed changes are necessary, and these are obtained by placing the driving belt on different steps of cone-pulley *P*, and also by the use of back-gears. The cone-pulley can be connected directly with the spindle or be disengaged

from it by means of bolt *m*. When the pulley and spindle are connected, five speeds (with this particular lathe) are obtained by simply shifting the driving belt to different steps of the cone. When a slower speed is required than can be obtained with the belt on the largest step of the cone, the latter is disconnected from the spindle, and the back-gears *G* and G_1, (shown in the plan view Fig. 2) are moved forward into mesh by turning handle *O;* the drive is then from cone-pulley *P* and gear *L* to gear *G*, and from gear G_1 to the large gear *J* on the spindle. When driving through the back-gears, five more speed changes are obtained by shifting the position of the driving belt, as before. Changes of feed for the tool are also required, and these are obtained by shifting the belt operating on pulleys *p* and p_1 to different-sized steps.

Front and rear views of the carriage apron, which contains the

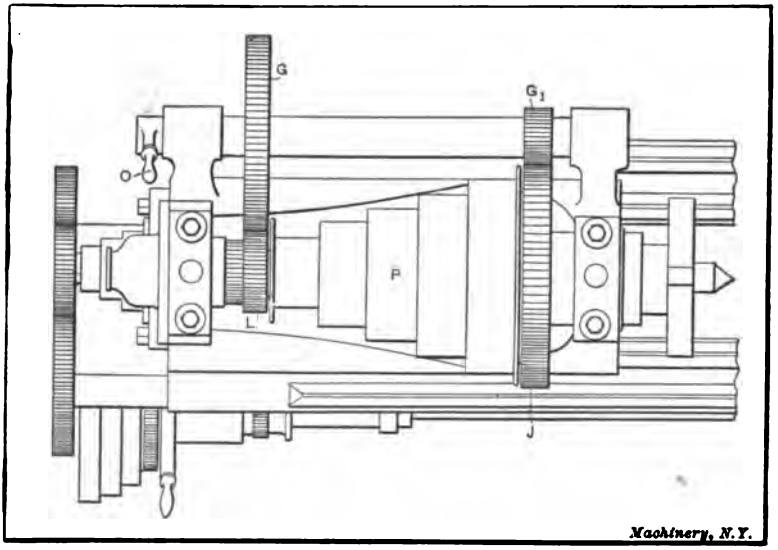


Fig. 2. Plan View of Headstock showing Back-gears

feeding mechanism, are shown in Figs. 3 and 4, to indicate how the feeds are engaged and reversed. The feed-rod *R* (Fig. 1) drives the small bevel gears *A* and A_1 (Figs. 3 and 4) which are mounted on a slide *S* that can be moved by lever *r* to bring either bevel gear into mesh with gear *B*. Gear *B* is attached to pinion *b* (see Fig. 3) meshing with gear *C*, which, when knob *k* is tightened, is locked by a friction clutch to pinion *c*. The latter pinion drives gear *D* which rotates shaft *E*. A pinion cut on the end of shaft *E* engages rack *K* (Fig. 1) attached to the bed, so that the rotation of *E* (which is controlled by knob *k*) moves the carriage along the bed. To reverse the direction of the movement, it is only necessary to throw gear *A* into mesh and gear A_1 out, or *vice versa*, by operating lever *r*. When the carriage is traversed by hand, shaft *E* and gear *D* are rotated by pinion d_1 connected with handle *d*.

The drive for the cross-feed is from gear *C* to gear *F* which can be engaged through a friction clutch (operated by knob *l*) with gear *G* meshing with a pinion *H*. The latter rotates the cross-feed screw, which passes through a nut attached to slide *D* (Fig. 1), thus moving

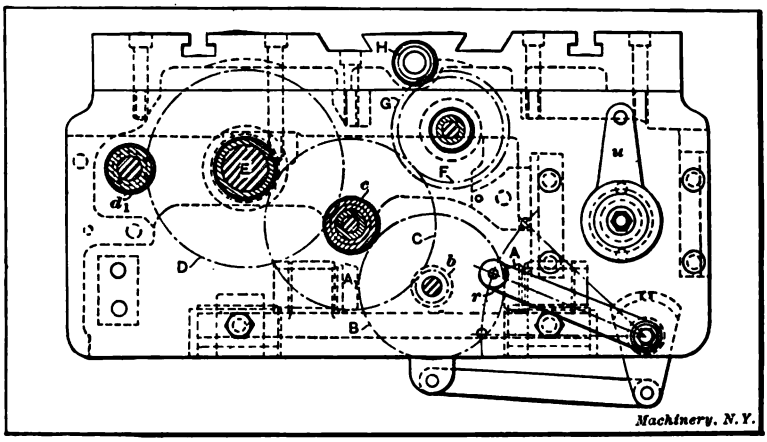


Fig. 3. Lathe Apron

the latter at right angles to the ways of the bed. The cross-feed is also reversed by means of lever *r*. As previously explained, lead-screw *S* is only used for feeding the carriage when cutting threads. The carriage is engaged with this screw by means of two half-nuts *N*

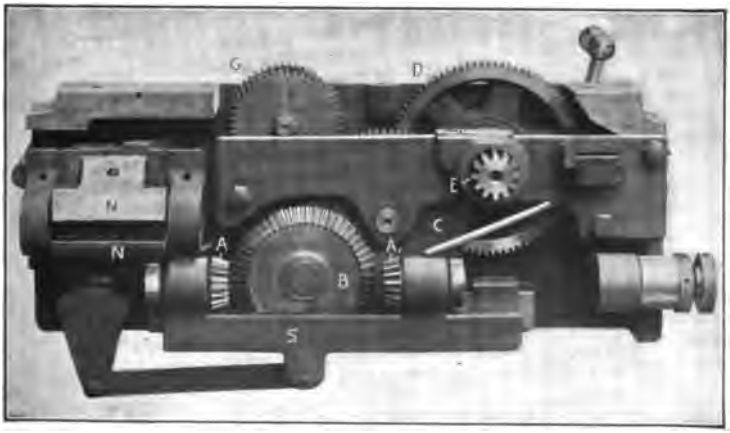


Fig. 4. Rear View of Lathe Apron

that are free to slide vertically and are closed around the screw by operating lever *u*. These half-nuts can only be closed when lever *r* is in a central or neutral position, so that the screw feed and the regular turning feed cannot be engaged at the same time.

CHAPTER II

EXAMPLE OF CYLINDRICAL TURNING

Having now considered the principal features of what might be called a standard lathe, the method of using it in the production of machine parts will be explained. The first example of work that will be referred to is shown in Fig. 6, which represents a drawing of the part. It is a steel shaft, the diameter of which must be 2¼ inches and the length 14½ inches, these being the finished dimensions. We will assume that the rough stock is cut off to a length of 14⅝ inches and has a diameter of 2⅝ inches. The first step in this operation is to form conically shaped center-holes in each end of the piece as indi-

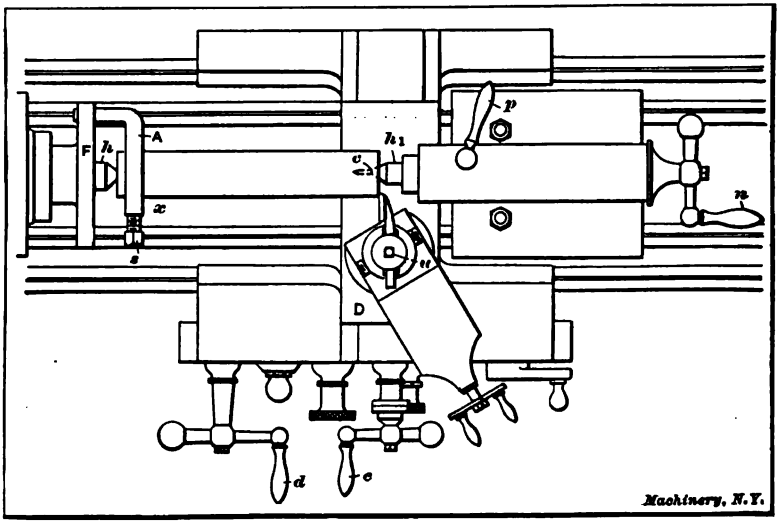


Fig. 5. Plan View showing Work Mounted Between Centers

cated at *c* in Fig. 5. As all work of this kind is held, while being turned, between the centers *h* and h_1, holes corresponding in shape to these centers are necessary to keep the work in place. There are several methods of forming these center-holes, as explained in Chapter III.

After the work is centered, a dog *A* is clamped to one end by tightening screw *s*, and is then placed between the centers. The dog has a projecting end or tail, as it is commonly called, which enters a slot in the faceplate *F* and thereby drives or rotates the work, when power is applied to the lathe spindle onto which the faceplate is screwed. The tailstock center h_1, after being oiled, should be set up just tight enough to eliminate all play, without interfering with a

free rotary movement of the work. This is done by turning handle *n*, and when the center is properly adjusted, the tailstock spindle containing the center is locked by tightening handle *p*.

Facing the Ends Square with a Side Tool

Everything is now ready for the turning operation. The ends of the piece should be faced square before turning the body to size, and the tool for this squaring operation is shown in Fig. 7; this is known

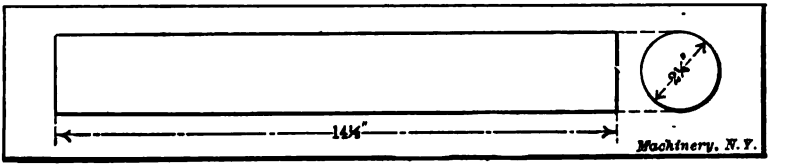


Fig. 6. Example of Plain Cylindrical Work

as a side tool. It has a cutting edge *e* which shaves off the metal as indicated in the end view by the dotted lines. The side *f* is ground to an angle so that when the tool is moved in the direction shown by the arrow, the cutting edge will come in contact with the part to be turned; in other words, side *f* is ground so as to provide clearance for the cutting edge. In addition, the top surface against which the chip bears, is beveled to give the tool keenness so that it will cut easily. As the principles of tool grinding are treated separately in Chapter V of MACHINERY'S Reference Book, No. 92, we shall for the present consider the tool's use rather than its form. For facing the end, the side tool is clamped in the toolpost by tightening the screw *u*,

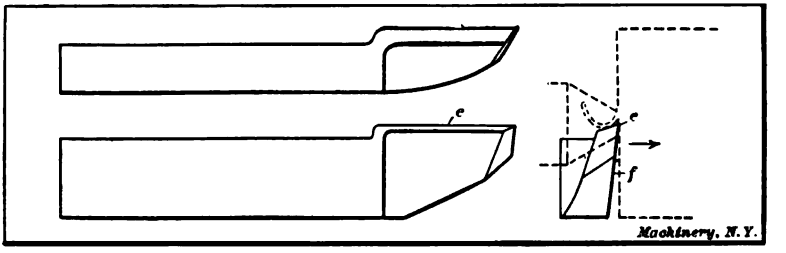


Fig. 7. Right-side Tool

Fig. 5, and it should be set with the cutting edge slightly inclined from a right-angled position as shown. The cutting edge should also be about the same height as the center of the work. When the tool is set, the lathe (if belt-driven) is started by shifting an overhead belt and the tool is then moved in until the point is in the position shown at *A*, Fig. 8. The tool-point is then fed against the end by handle *d*, Fig. 5, until a light chip is being turned off, and then it is moved outward by handle *e* (as indicated by the arrow at *B*, Fig. 8), the carriage remaining stationary. As the movement of the tool-point is guided by the cross-slide *D*, which is at right angles with the axis of the work, the end will be faced square. For short turning operations of this

kind, the power feeds are not used as they are intended for comparatively long cuts. If it were necessary to remove much metal from the end, a number of cuts would be taken across the end; in this case, however, the rough stock is only ⅛ inch too long so that this end need only be made true. After taking a cut as described, the surface, if left rough by the tool-point, should be made smooth by a second or finishing cut. If the tool is ground slightly round at the point and the cutting edge is set almost square, as at *C*, Fig. 8, a smooth finish can be obtained; the cut, however, should be light and the outward feed uniform. The work is next reversed in the centers and the driving dog is placed on the end just finished; the other end is then faced, enough metal being removed to make the piece 14½ inches long, as called for on the drawing. This completes the facing operation.

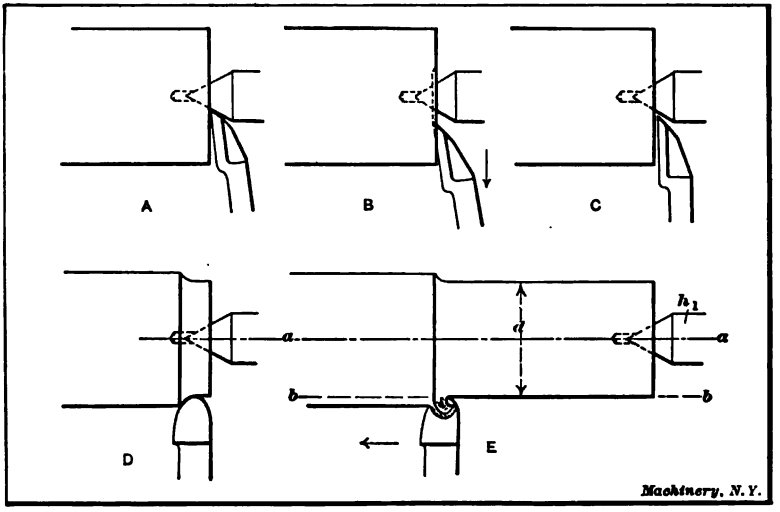


Fig. 8. Facing End with Side Tool and Turning Work Cylindrical

If the end of the work does not need to be perfectly square, the facing operation can be performed by setting the tool in a right-angled position and then feeding it sidewise, thus removing a chip equal to the width of one side. Evidently this method is confined to comparatively small diameters and the squareness of the turned end will be determined by the position of the tool's cutting edge.

Lathe Turning Tool—Turning Work Cylindrical

The tool used to turn the body to the required diameter is shaped differently from the side tool, the cutting edge *E* being curved as shown in Fig. 9. A tool of this shape can be used for a variety of cylindrical turning operations. As most of the work is done by that part of the edge marked by arrow *a*, the top of the tool is ground to slope back from this part to give it keenness. The end *F*, or the flank, is also ground to an angle to provide clearance for the cutting

edge; for without such clearance, the flank would rub against the work and the cutting edge would be ineffective. This type of tool is placed about square with the work, for turning, and with the cutting end a little above the center.

Before beginning to turn, a pair of outside calipers should be set

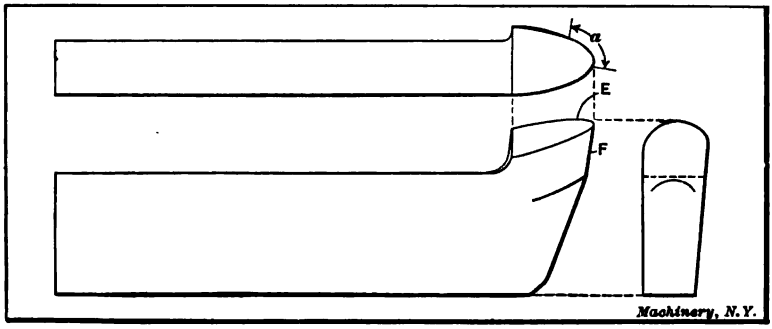


Fig. 9. Tool used for Cylindrical Turning

to 2¼ inches, which, in this case, is the finished diameter of the work. Calipers are sometimes set by using a graduated scale as at *A*, Fig. 10, or they can be adjusted to fit a standard cylindrical gage of the required size as at *B*. Very often fixed caliper gages *C* are used instead of the adjustable spring calipers. These fixed gages, sometimes called "snap" gages, are accurately made to different sizes, and they

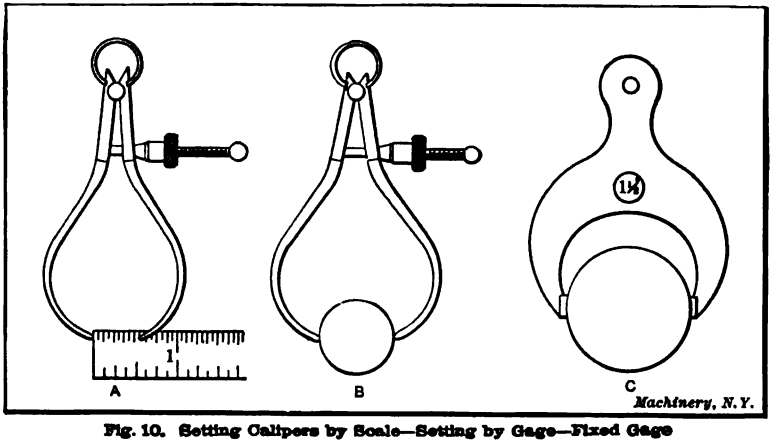


Fig. 10. Setting Calipers by Scale—Setting by Gage—Fixed Gage

are particularly useful when a number of pieces have to be turned to exactly the same size.

The turning tool is started at the right end of the work and the carriage should be moved with the left hand when beginning a cut, as shown in Fig. 11, in order to have the right hand free for calipering. A short space is first turned by hand feeding, as at *D*, Fig. 8, and when the calipers show that the diameter is slightly greater than the

finished size (to allow for a light finishing cut), the power feed for the carriage is engaged; the tool then moves along the work reducing it as at *E*. Evidently, if the movement is along a line *b*—*b*, parallel with the axis *a*—*a*, the diameter *d* will be the same at all points, and a true cylindrical piece will be turned. On the other hand, if the axis *a*—*a* is inclined one way or the other, the work will be made tapering; in fact, the tailstock center h_1 can be adjusted laterally for turning tapers, but for straight turning, both centers must be in alignment with the carriage travel. Most lathes have lines on the stationary and movable parts of the tailstock base which show when the centers are set for straight turning. These lines, however, may not be absolutely correct, and it is good practice to test the alignment of the centers before beginning to turn. This can be done by taking

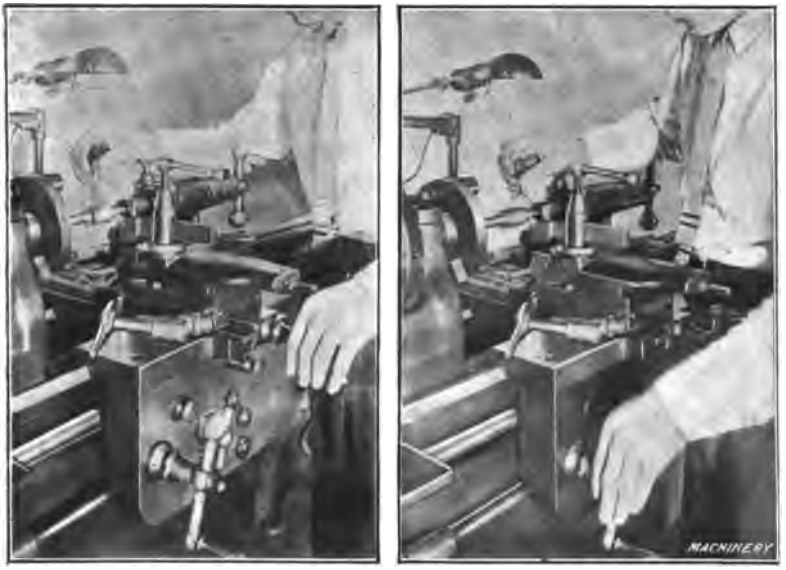


Fig. 11. Views showing how the Cross-slide and Carriage are Manipulated by Hand when Starting a Cut

trial cuts, at each end of the work (without disturbing the tool's crosswise position), and then comparing the diameters, or by testing the carriage travel with a true cylindrical piece held between the centers.

If the relative positions of the lathe centers is not known, the work should be calipered as the cut progresses to see if the diameter *d* is the same at all points. In case the diameter gradually increases, the tailstock center should be shifted slightly to the rear before taking the next cut, but if the diameter gradually diminishes, the adjustment would, of course, be made in the opposite direction. The diameter is tested by attempting to pass the calipers over the work. When the measuring points just touch the work as they are gently passed

across it, the diameter being turned is evidently the same as the size to which the calipers are set.

As the driving dog is on one end, the cut cannot be taken over the entire length, and when the tool has arrived at say position x, Fig. 5, it is returned to the starting point and the work is reversed in the centers. The large end is then turned, and if the cross-slide has not been moved, the tool will meet the first cut. The two cuts will not be joined or blended together perfectly, however, and for this reason a cut should be continuous when this is possible.

Roughing and Finishing Cuts

Ordinarily in lathe work, as well as in other machine work, there are two classes of cuts, known as roughing and finishing cuts. Roughing cuts are for reducing the work as quickly as possible almost to

Fig. 12. Filing Work after Finishing Cut is taken

the required size, whereas finishing cuts, as the name implies, are intended to leave the part smooth and of the proper size. When the rough stock is only a little larger than the finished diameter, a single cut is sufficient, but if there is considerable metal to turn away, one or more deep roughing cuts would have to be taken, and, finally, a light cut for finishing. In this particular case, one roughing and one finishing cut would doubtless be taken, as the diameter has to be reduced $\frac{3}{8}$ inch. Ordinarily the roughing cut would be deep enough to leave the work about 1/32 or perhaps 1/16 inch above the finished size. When there is considerable metal to remove and a number of roughing cuts have to be taken, the depth of each cut and the feed of the tool are governed largely by the pulling power of the lathe and the strength of the work to withstand the strain of a heavy cut.

Of course, just as few cuts as possible should be taken in order to save time. The speed of the work should also be as fast as the conditions will allow for the same reason, but as there are many things which govern the speed, the feed of the tool, and the depth of the cut, these important points are referred to separately in Chapter III of MACHINERY'S Reference Book No. 92.

Filing and Finishing

In many cases the last or finishing cut does not leave as smooth a surface as is required and it is necessary to resort to other means. The method commonly employed for finishing in the lathe is by the use of a file and emery cloth. The work is rotated considerably faster for filing than for turning, and the entire surface is filed by a flat, single-cut file, held as shown in Fig. 12. The file is passed across the work and advanced sidewise for each forward stroke until the entire surface is finished. The file should be kept in contact with the work continually, but on the return stroke, the pressure should be relieved.

The movement of the file during the forward or cutting stroke should be much slower than when filing in a vise. By moving the file slowly, the work can make a number of revolutions for each stroke, which tends to keep it round, as practically the same amount of metal is removed from the entire circumference. On the other hand, short rapid strokes tend to produce flat spots, or at least an irregular surface, especially if the work can only make part of a revolution for each cutting stroke. The pressure on the file during the forward stroke, should also be kept as nearly uniform as possible. It is very difficult to file a part smooth and at the same time to keep it round and cylindrical, and the more filing that has to be done, the greater the chance of error. For this reason, the amount left for filing should be very small; in fact, the metal removed by filing should be just enough to take out the tool marks and give a smooth finish. Very often a satisfactory finish can be obtained with a turning tool, and filing is not necessary at all.

Sometimes particles of metal collect between the teeth of a file and make deep scratches as the file is passed across the work. When this occurs, the teeth should be cleaned by using a wire brush or a file card, which is drawn across the file in the direction of the teeth. This forming of tiny particles between the teeth is known as "pinning" and it can sometimes be avoided by rubbing chalk on the file. Filing is not only done to obtain a smooth finish, but also to reduce the work to an exact diameter, as a very slight reduction can be made in this way. If a polish is desired, this can be obtained by holding a piece of emery cloth tightly around the work as it revolves. Most cylindrical parts can be finished more quickly and accurately in the grinder than in the lathe, and many classes of work are, at the present time, simply rough-turned in the lathe and then ground to size in a cylindrical grinding machine.

CHAPTER III

CENTERING

As mentioned in the preceding chapter, there are a number of different methods of forming center-holes in the ends of parts that have to be turned while held between lathe centers. A method of centering light work, which requires few special tools, is first to locate a central point on the end and then drill and ream the center-hole by using the lathe itself.

Locating the Center—Drilling in the Lathe

Hermaphrodite dividers are useful for finding the center, as illustrated at *A*, Fig. 13, but if the work is fairly round, a center-square *B* is preferable. A line is scribed across the end and then another line at right angles to the first by changing the position of the square; the

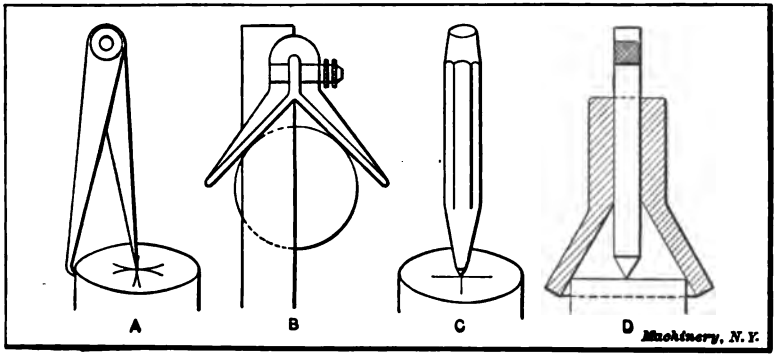


Fig. 13. Centering End with Punch preparatory to Drilling

intersection of these two lines will be the center, which should be marked by striking a pointed punch *C* with a hammer. If a cup or bell center-punch *D* is available, it will not be necessary to first make center lines, as the conical part shown locates the punch in a central position. This style of punch should only be used on work which is fairly round.

After small centers have been located in both ends, their position can be tested by placing the work between the lathe centers and rotating it rapidly by drawing the hand quickly across it. By holding a piece of chalk close to the work as it spins around, a mark will be made on the "high" side if the centers are not accurate; the centers are then shifted toward these marks. If the work is close to the finished diameter, the centers should, of course, be located quite accurately in order that the entire surface of the work will be turned true when it is reduced to the finished size.

One method of finishing these center-holes is indicated in Fig. 14. A chuck *C* is screwed onto the spindle in place of the faceplate, and

a combination center drill and reamer *R* is gripped by the chuck jaws and set to run true. The center is then drilled and reamed at one end by pressing the work against the revolving drill with the tailstock spindle, which is fed out by turning handle *n*. The piece is then reversed for drilling the opposite end. The work may be kept from revolving while the centers are being drilled and reamed, by attaching

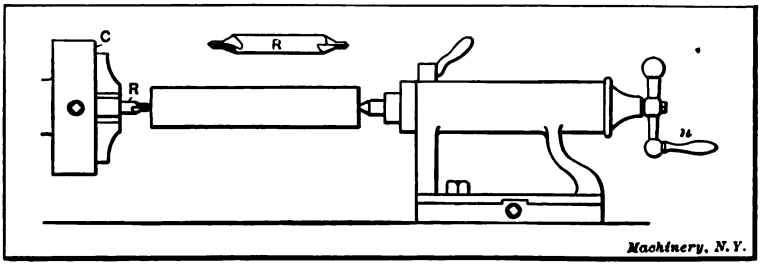
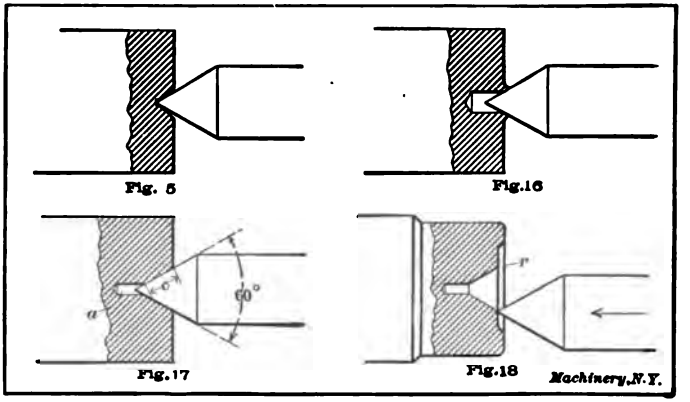


Fig. 14. Drilling Centers in the Lathe

a dog to it close to the tailstock end and then adjusting the cross-slide until the dog is in contact with it. From the foregoing it will be seen that the small centers made by punch *C*, Fig. 13, serve as a starting point for the drill and also as a support for the outer end of the work while the first hole is being drilled.

The form of center-hole produced by a combination drill and reamer is shown in Fig. 17. A small straight hole *a* in the bottom prevents



Figs. 15 to 18. Centers of Incorrect and Correct Form

the point of the lathe center from coming in contact with the work and insures a good bearing on the conical surface *c*. The standard angle for lathe centers is sixty degrees, as the illustration shows, and the tapering part of all center-holes should be made to this angle.

Centering Machine

Many shops have a special machine for forming centers which enables the operation to be performed quickly. One type of centering machine is shown in Fig. 19. The work is gripped in a chuck *C*

that automatically locates it in a central position so that it is not necessary to lay out the end before drilling. There are two spindles s and s_1 one of which holds the drill and the other the countersink, and these are rotated by a belt passing over pulley P. Each of these spindles is advanced by lever L and either of them can be moved to a position central with the work, as they are mounted in a swiveling frame. In operating this machine, a small straight hole is first made by a twist drill held in one of the spindles; the other spindle is then moved over to the center and the hole is reamed tapering. The

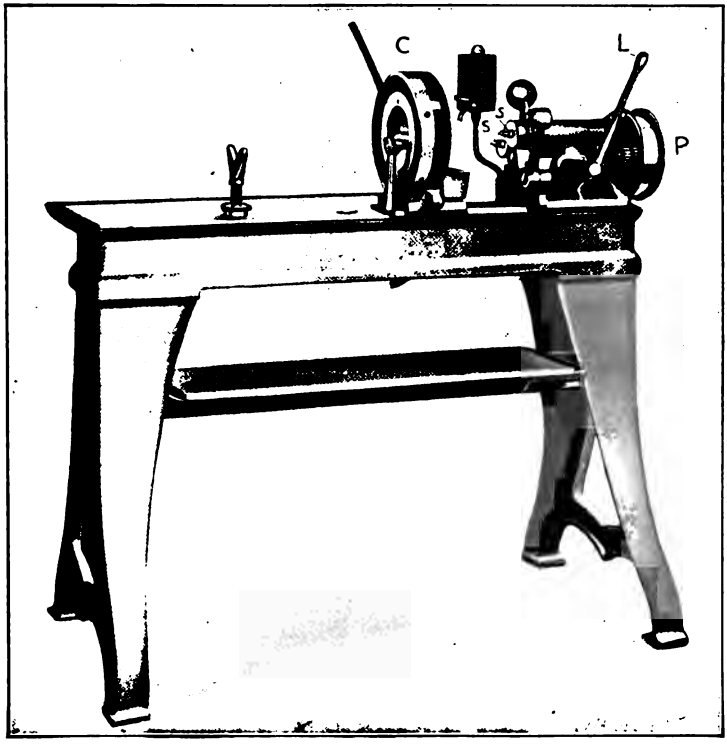


Fig. 19. Special Machine for Centering

arrangement is such that neither spindle can be advanced by the feeding lever except when in a central position. The amount that each spindle can be advanced is limited by a fixed collar inside the head, and there is also a swinging adjustable stop against which the end of the work should be placed before tightening the chuck. These two features make it possible to ream center holes of the same size or depth in any number of pieces.

Different Forms of Centers

In some poorly equipped shops it is necessary to form centers by the use of a center-punch only, as there is no better tool. If the end

of the punch has a sixty-degree taper, a fair center can be formed in this way, but it is not a method to be recommended, especially when accurate work is required. Sometimes centers are made with punches that are too blunt, producing a shallow center, such as the one shown in Fig. 15. In this case all the bearing is on the point of the lathe center, which is the worst possible place for it. Another way is to simply drill a straight hole as in Fig. 16; this is also bad practice

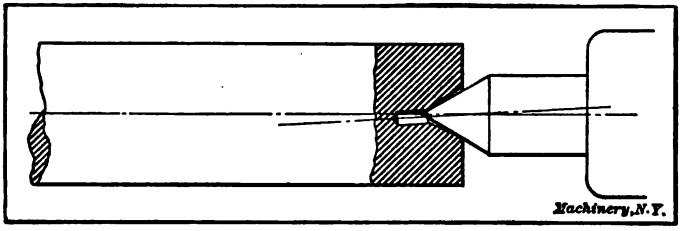


Fig. 20. The Imperfect Center Bearing is the Result of Centering before Straightening

in more than one respect. Fig. 18 shows a form of center which is often found in the ends of lathe arbors, the mouth of the center being rounded, at *r*, and the arbor end recessed as shown. The rounded corner prevents the point of the lathe center from catching when it is moved rapidly towards work which is not being held quite centrally, and the end is recessed to protect the center against bruises. Stock that is bent should always be straightened before the centers are drilled and reamed. If the work is centered first and then straightened,

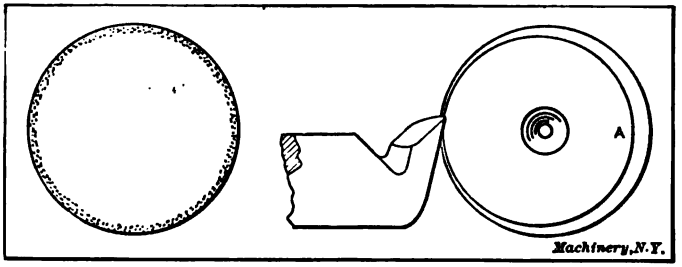


Fig. 21. Tool Steel should be centered Concentric, in order to remove the Decarbonized Outer Surface

the bearing on the lathe center would be as shown in Fig. 20. The center will then wear unevenly with the result that the surfaces last turned will not be concentric with those which were finished first.

Precaution When Centering Tool Steel

Ordinarily centers are so located that the stock runs approximately true before being turned, but when centering material to be used in making tools, such as reamers, mills, etc., which need to be hardened, particular care should be taken to have the rough surface run fairly true. This is not merely to insure that the piece will "true-up," as there is a more important consideration the disregard of which often

affects the quality of the finished tool. As is well known, the degree of hardness of a piece of tool steel that has been heated and then suddenly cooled, depends upon the amount of carbon that it contains, steel that is high in carbon becoming much harder than that which contains less carbon. Furthermore the amount of carbon found at the surface, and to some little depth below the surface of a bar of steel, is less than the carbon contained in the rest of the bar. This is illustrated diagrammatically in Fig. 21 by the shaded area in the view to the left. (This decarbonization is probably due to the action of the oxygen of the air on the bar during the process of manufacture.) If stock for a reamer is so centered that the tool removes the decarbonized surface only on one side, as illustrated to the right, evidently when the reamer is finished and hardened, the teeth on the side *A* will be harder than those on the opposite side, which would not have been the case if the rough bar had been centered true. To

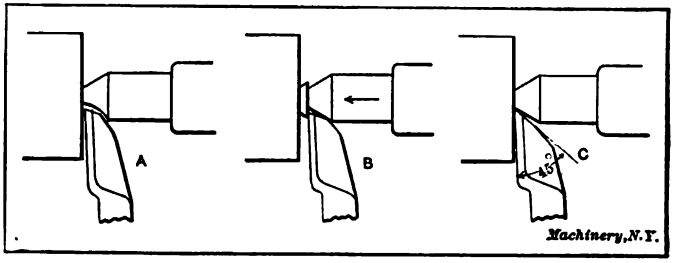


Fig. 22. Three Methods of Facing the End Square

avoid any trouble of this kind, stock that is to be used for hardened tools, should be enough larger than the finished diameter and so centered that this decarbonized surface will be entirely removed in turning.

Facing the Ends of Centered Stock

As a piece of work is not properly centered until the ends are faced square, we will consider this operation in connection with centering. Some machinists prefer lathe centers that are cut away as shown at *A*, Fig. 22, so that the point of the side tool can be fed in far enough to face the end right up to the center hole. Others, instead of using a special center, simply loosen the regular one slightly and then, with the tool in a position as at *B*, face the projecting teat by feeding both tool and center inward as shown by the arrow. Whenever this method is employed, care should be taken to remove any chips from the center hole which may have entered. A method which makes it unnecessary to loosen the regular center, or to use a special one, is to provide clearance for the tool-point by grinding it to an angle of approximately forty-five degrees, as shown at *C*. If the tool is not set too high, it can then be fed right up to the lathe center and the end squared without difficulty. As for the special center *A*, the use of special tools and appliances should always be avoided unless they effect a saving in time or their use makes it possible to accomplish the same end with less work.

CHAPTER IV

THE USE OF LATHE MANDRELS

When it is necessary to turn the outside of a part having a hole through it, centers cannot, of course, be drilled in the ends and other means must be resorted to. We shall assume that the bushing *B*, Fig. 24, has a finished hole through the center, and it is desired to turn the outside cylindrical and concentric with the hole. This could be done by forcing a tightly-fitted mandrel *M*, having accurately-centered ends, into the bushing, and inserting the mandrel and work between the lathe centers h and h_1 as shown. Evidently, if the mandrel runs true on its centers, the hole in the bushing will also run true and the outside can be turned the same as though the mandrel and

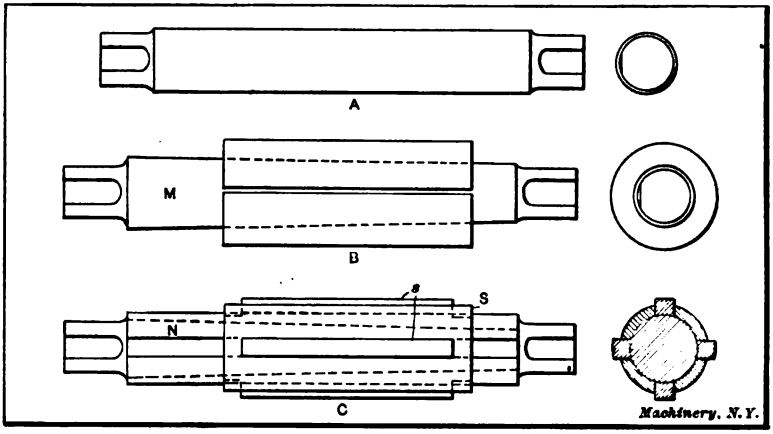


Fig. 23. Different Types of Mandrels

bushing were a solid piece. From this it will be seen that a mandrel simply forms a temporary support for work that is bored and therefore cannot be centered.

Another example of work that would be turned on an arbor is shown in Fig. 25. This is a small cast-iron wheel having a finished hole through the hub, and the outer surface and sides of the rim are to be turned true with this hole. In this case, the work would also be held by pressing a mandrel through the hub as shown. This method, however, would only apply to comparatively small wheels because it would be difficult, if not impossible, to prevent a large wheel from turning on the arbor when taking a cut, and even if it could be driven, large work could be done to better advantage on another type of machine. (The vertical boring mill is used extensively for turning

arge wheels). When turning the outside of the rim, a tool similar
that shown at *t* should be used, but for facing or turning the sides,
might be better, if not necessary, to use tools having bent ends
shown by the dotted lines; in fact, turning tools of various kinds
are made with the ends bent to the right or left, as this enables

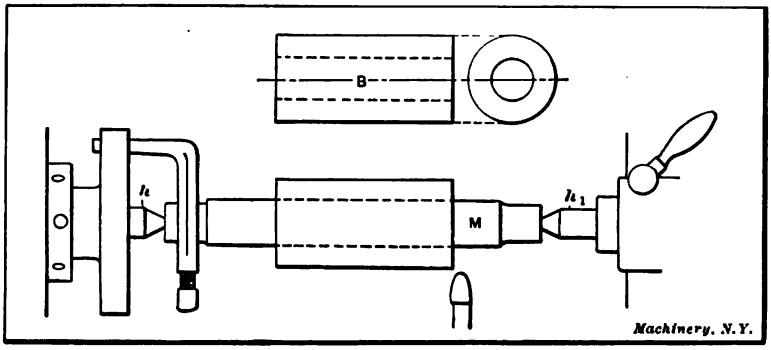


Fig. 24. Bushing mounted on Mandrel for Turning

them to be used on surfaces that could not be reached very well with a straight tool.

If a comparatively large pulley is mounted near the end of the mandrel, it can be driven directly by pins attached to the faceplate and

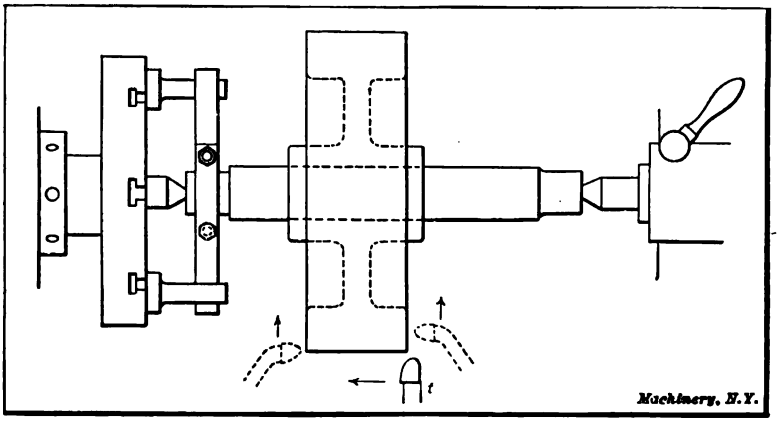


Fig. 25. Turning Pulley Held on Mandrel

engaging the pulley arms. When this method is employed, a dog is, of course, unnecessary.

Different Types of Lathe Mandrels

Three different types of lathe mandrels are shown in Fig. 23. The kind shown at *A* is usually made of tool steel and the body is finished to a standard size. The ends are somewhat reduced and flat spots are milled, as shown, to give the clamping screw of the dog a good

grip. This type is used very extensively, but in shops where a great variety of work is being done and there are many odd-sized holes, the expanding mandrel *B* can be used to advantage. This type, instead of being solid, consists of a tapering inner mandrel *M* on which is placed a split bushing that can be expanded, within certain limits, by driving in the tapering member. The advantage of this type is that a compartively small stock of mandrels is required, as different sized bushings can be used. This type can also be fitted to holes of odd sizes, whereas a solid mandrel must be provided for each different size of hole. The latter are, however, more accurate than the expanding type. Another form of expanding mandrel is shown at *C*. This type has a straight body *N* in which four tapering grooves are cut lengthwise, as shown, and there is a sleeve *S*, containing four slots that are located to correspond with the tapering grooves. Strips *s* are fitted in these slots, and as the part *N* is driven in, the strips are moved outward as they ascend the tapering grooves. By having different sets of these strips of various heights, one mandrel of this type can be made to cover quite a range of sizes. It is not suited, however, to thin work, as the pressure, being concentrated in four places, would spring it out of shape.

Fig. 26. Press for Forcing Mandrels into Work

Particular care should be taken to preserve the accuracy of the centers of lathe mandrels by keeping them clean and well-oiled while in use.

Mandrel or Arbor Press

The best method of inserting a mandrel in a hole is by using a press, Fig. 26, designed for that purpose, but if such a press is not available and it is necessary to drive the mandrel in, a "soft" hammer, made of copper, lead or other soft material, should be used to protect the end of the mandrel. In either case, the mandrel should not be

forced in too tightly, for if it fits properly, this will not be necessary in order to hold the work securely. On the other hand, the work might easily be broken by attempting to force the mandrel in as far and as tightly as possible. In using the arbor press, the work is placed on the base *B* with the hole in a vertical position, and the arbor (which should be oiled slightly) is forced down into it by ram *R*, operated by lever *L*. Slots are provided in the base, as shown, so that the end of the arbor can come through at the bottom of the hole. The lever of this particular press is counterweighted so that it rises to a vertical position when released. The ram can then be adjusted quickly to any required height by the handwheel seen at the left.

Some shops are equipped with power-driven mandrel or arbor presses. This type is particularly desirable for large work, owing to the greater pressure required for inserting mandrels that are comparatively large in diameter. One well-known type of power press is driven by a belt, and the downward pressure of the ram is controlled by a handwheel. The ram is raised or lowered by turning this handwheel in one direction or the other, and a gage shows how much pressure is being applied. This type of press can also be used for other purposes, such as forcing bushings or pins into or out of holes, bending or straightening parts, or for similar work.

CHAPTER V

CHUCK AND FACEPLATE WORK

Many parts that are turned in the lathe are so shaped that they cannot be held between the lathe centers like shafts and other similar pieces and it is often necessary to hold them in a chuck *A*, Fig. 27, which is screwed on the lathe spindle instead of the faceplate. The work is gripped by the jaws *J* which can be moved in or out to accommodate various diameters. There are three classes of chucks ordinarily used on the lathe, known as the independent, universal, and combination types. The independent chuck is so named because each jaw can be adjusted in or out independently of the others by turning the jaw screws *S* with a wrench. The jaws of the universal chuck all move together and keep the same distance from the center, and

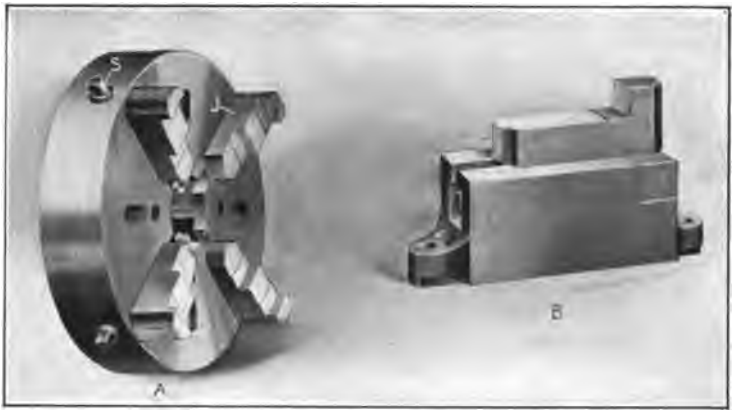


Fig. 27. Chuck and Faceplate Jaw

they can be adjusted by turning any one of the screws *S*, whereas with the independent type the chuck wrench must be applied to each jaw screw. The combination chuck, as the name implies, may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects as it is usually stronger and adapted for holding odd-shaped pieces because each jaw can be set to any required position.

Radial Facing or Turning

As an example of chuck work, we shall assume that the sides of disk *D*, Fig. 28, are to be turned flat and parallel with each other and that an independent chuck is to be used. First the chuck is

screwed on the lathe spindle (after removing the faceplate) by holding it with the right hand and turning the lathe spindle with the left by pulling down on the belt. The chuck jaws are then moved out or in, as the case may be, far enough to receive the disk and each jaw is set about the same distance from the center by the aid of concentric circles on the face of the chuck. The jaws are then tightened while the disk is held back against them to bring the rough inner surface in a vertical plane. If the work is quite heavy, it can be held against the chuck, before the jaws are tightened, by inserting a piece of wood between it and the tailstock center; the latter is then run out far enough to force the work back. The outside or periphery of the disk should run nearly true and it may be necessary to move

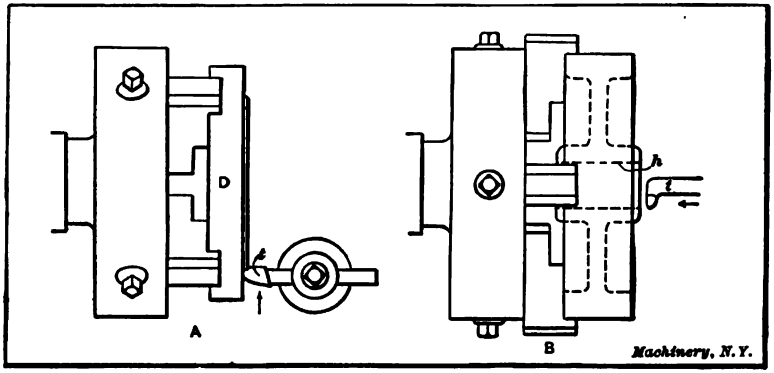


Fig. 28. Radial Facing—Boring Pulley Held in Chuck

the jaws in on one side and out on the other to bring the disk to a central position. To test its location, the lathe is run at a moderate speed and a piece of chalk is held near the outer surface. If the latter runs out, the "high" side will be marked by the chalk, and this mark can be used as a guide in adjusting the jaws. It should be remembered that the jaws are moved only one-half the amount that the work runs out.

A round-nosed tool *t* of the shape shown is used for radial facing or turning operations of the kind illustrated. This tool is similar to the kind used when turning between centers, the principal difference being in the direction of the top slope. The radial facing tool should be ground to slope downward toward *a* (see Fig. 29) whereas the regular turning tool slopes toward *b*, the inclination in each case being away from that part of the cutting edge which does the work. The cutting edge should be the same height as the lathe centers, and the cut is taken by feeding the tool from the outside in to the center. The cut is started by hand and then the power feed is engaged, except for small surfaces. The first cut should, if possible, be deep enough to get beneath the scale, especially if turning cast iron, as a tool which just grazes the hard outer surface in spots will be dulled in a comparatively short time. If it were simply necessary to turn a

true flat surface and the thickness of the disk were immaterial, two cuts would be sufficient, unless the surface were very uneven, the first or roughing cut being followed by a light finishing cut. For a finishing cut, the same tool could be used but if there were a number of disks to be faced, a square-nosed tool *F*, Fig. 29, could probably be used to better advantage. This type has a broad flat cutting edge that is set parallel with the rough-turned surface and this broad edge

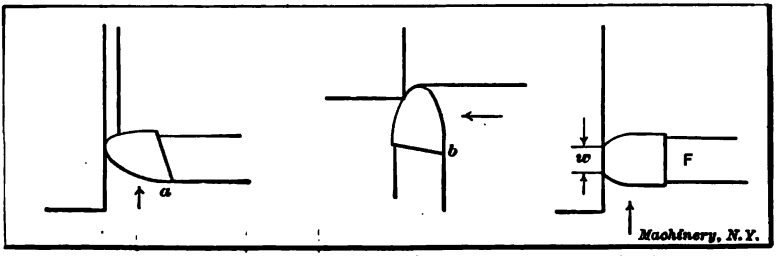


Fig. 29. Top of Tool should Slope away from Working Part of Cutting Edge

enables a coarse feed to be taken, thus reducing the time required for the finishing cut. If a coarse feed were taken with the round tool, the turned surface would have spiral grooves in it, whereas with the broad cutting edge, a smooth surface is obtained even though the feed is coarse. The amount of feed per revolution of the work, however, should always be less than the width w of the cutting edge. Very often broad tools cannot be used for finishing cuts, especially when turning steel, because their greater contact causes chattering and results in a rough surface. An old and worn lathe is more liable to chatter than one that is heavy and well-built, and as the diameter of the work also makes a difference, a broad tool cannot always be used for finishing, even though, theoretically, it would be preferable. After

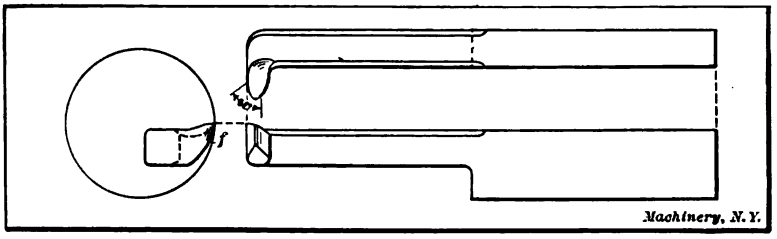


Fig. 30. Boring Tool

one side of the disk is finished, it is reversed in the chuck, the finished surface being placed against the jaws. The remaining rough side is then turned, care being taken when starting the first cut to caliper the width of the disk at several points to make sure that the two sides are parallel.

Example of Boring—Tool Used

Another example of chuck work is shown at *B*, Fig. 28. In this case a cast-iron pulley is to have a true hole h bored through the

hub. (The finishing of internal cylindrical surfaces in a lathe is referred to as boring rather than turning). The casting should be set true by the rim instead of by the rough-cored hole in the hub; this can be done by the use of chalk as previously explained. Even though a universal type of chuck were used, the jaws of which, as will be recalled, are self-centering, it might be necessary to turn the pulley relative to the chuck as a casting sometimes runs out because of

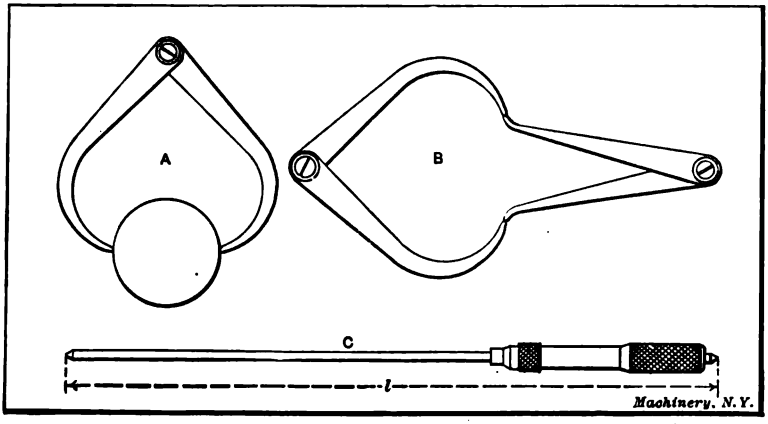


Fig. 31. Setting Outside Calipers—Transferring Measurement to Inside Calipers—Micrometer Gage

rough spots or lumps which happen to come beneath one or more of the jaws. The shape of tool *t* for boring is quite different from one used for outside turning, as shown by Fig. 30., The cutting end is forged approximately at right angles to the body or shank, and the

Fig. 32. Standard Plug Gage

top surface is ground to slope away from the working part *w* of the cutting edge, as with practically all turning tools. The front part or flank *f* is also ground away to give the edge clearance. This type of tool is clamped in the toolpost with the body about parallel with the lathe spindle, and ordinarily the cutting edge would be about as high as the center of the hole, or a little below if anything. When starting a cut, the tool is brought up to the work by moving the carriage and it is then adjusted radially to get the right depth of cut.

The power feed for the carriage is then used, the tool feeding back through the hole as indicated by the arrow, Fig. 28. In this case, as with all turning operations, the first cut should be deep enough to cut beneath the hard outer scale at every part of the hole. Usually a rough-cored hole is so much smaller than the finished size that several cuts are necessary; in any case the last or finishing cut should be

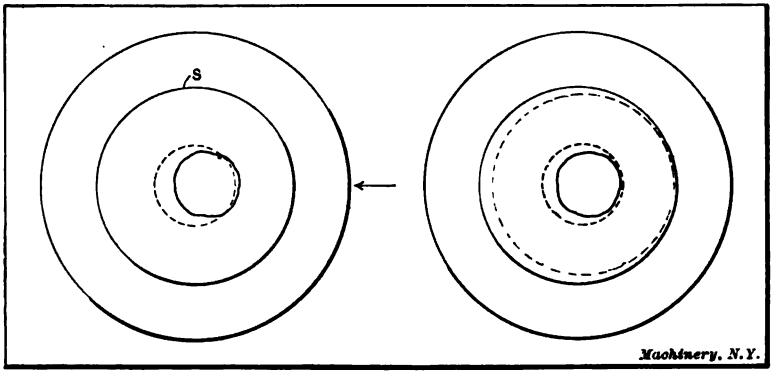


Fig. 33. Setting Work with reference to Surfaces to be Turned

very light to prevent the tool from springing away from the work, so that the hole will be as true as possible. Boring tools, particularly for small holes, are not as rigid as those used for outside turning, as the tool has to be small enough to enter the hole and for this reason comparatively light cuts have to be taken. When boring a

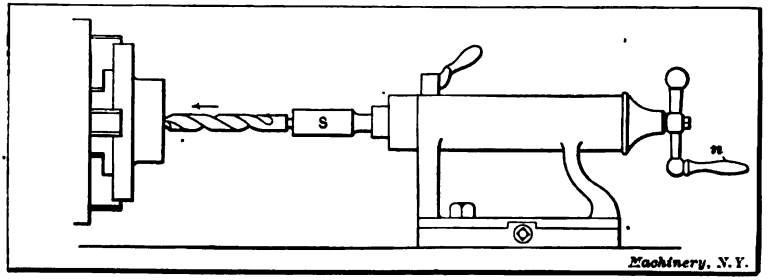


Fig. 34. Drilling in the Lathe

small hole, the largest tool that will enter it without interference should be used to get the greatest rigidity possible.

Measuring Bored Holes

The diameters of small holes that are being bored are usually measured with inside calipers or standard gages. If the pulley were being bored to fit over some shaft, the diameter of the shaft would first be measured by using outside calipers as shown at *A*, Fig. 31, the measuring points of the calipers being adjusted until they just made contact with the shaft when passed over it. The inside calipers are then set as at *B* to correspond with the size of the shaft, and the

hole is bored just large enough to admit the inside calipers easily. Very accurate measurements can be made with calipers, but to become expert in their use requires experience. Some mechanics never become proficient in the art of calipering because their hands are "heavy" and they lack the sensitiveness and delicacy of touch that is necessary. For large holes, a gage *C* is often used, the length *l* being adjusted to the diameter desired. Small holes are often bored to fit hardened steel plug gages (Fig. 32), the cylindrical measuring ends of which are made with great accuracy to standard sizes. This type of gage is particularly useful when a number of holes have to be bored to the same size, all holes being made just large enough to fit the gage without any perceptible play.

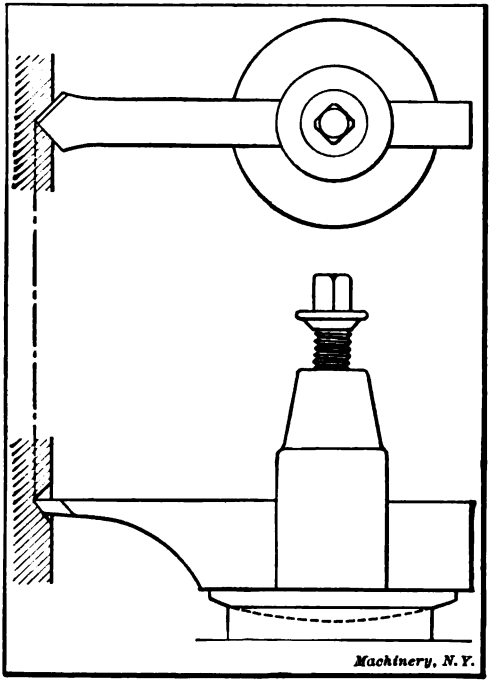


Fig. 35. Special Tool which Forms a Center for Starting the Drill

Setting Work in the Chuck

When setting a part in a chuck, care should be taken to so locate it that every surface to be turned will be true when machined to the finished size. As a simple illustration, let us assume that the hole through the cast-iron disk, Fig. 33, has been cored considerably out of center as shown. If the work is set by the outside surface *S*, as it would be ordinarily, the hole is so much out of center that it will not be true when bored to the finished size, as indicated by the dotted lines. On the other hand, if the rough hole is set true, the outside cannot be finished all over, without making the diameter too small, when it is finally turned. In such a case, the casting should be shifted, as shown by the arrow, to divide the error between the two surfaces, both of which can then be turned as shown by the dotted lines in the view to the right. This principle of dividing the error when setting work can often be applied in connection with turning and boring. Hence, after a casting or other part has been set true by the most important surface, all other surfaces which require machining should then be tested to make sure that they all can be finished to the proper size.

Drilling and Reaming

When a hole is to be bored from the solid, it is necessary to drill a hole before a boring tool can be used. One method of drilling in the lathe is to insert an ordinary twist drill in a holder or socket *S*, Fig. 34, fitted in the tailstock spindle in place of the center. The drill is then fed through the work by turning the handle *n* and feeding the spindle outward as shown by the arrow. Before beginning to drill, it is well to turn a conical spot or center for the drill point by using a special tool, Fig. 35, having a point like a flat drill. This tool is clamped in the toolpost with the point at the same height as the lathe centers. It is then moved to the center of the work and a conical center is turned as shown by the sectional view. If the drill were not given this true starting point, it probably would enter the work more or less off center. Drills can also be started without

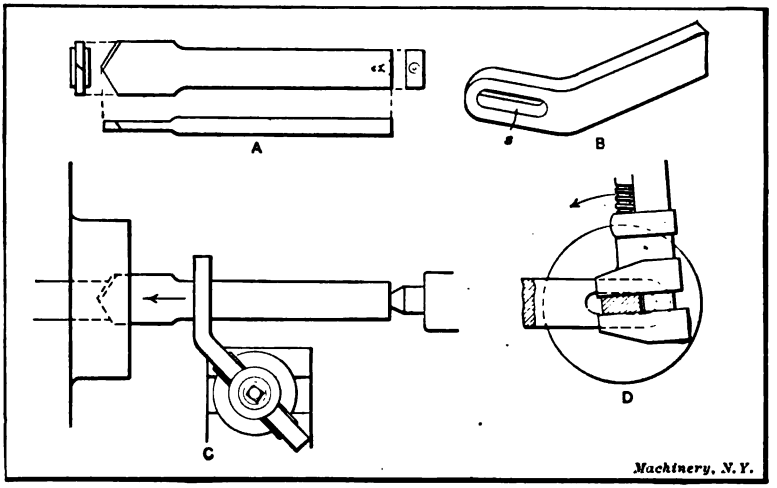


Fig. 86. Flat Drill and Holder

turning a center by bringing the square end or butt of a tool-shank held in the toolpost, in contact with the drill near the cutting end. If the point starts off center, thus causing the drill to wobble, the stationary tool-shank will gradually force or bump it over to the center.

Small holes are often finished in the lathe by drilling and reaming without the use of a boring tool. The form of drill that is used quite extensively for drilling cored holes in castings is shown in Fig. 36 at *A*. This drill is flat and the right end has a large center hole for receiving the center of the tailstock. To prevent the drill from turning, a holder *B*, having a slot *s* in its end through which the drill passes, is clamped in the toolpost, as at *C*. This slot should be set central with the lathe centers, and the drill, when being started, should be held tightly in the slot by turning or twisting it with a wrench as indicated in the end view at *D;* this steadies the drill and causes

it to start fairly true even though the cored hole runs out considerably.

Another style of tool for enlarging cored holes is shown in Fig. 37, at *A*. This is a rose chucking reamer, having beveled cutting edges on the end and a cylindrical body, which fits closely in the reamed hole, thus supporting and guiding the cutting end. The reamer shown at *B* is a fluted type with cutting edges that extend from *a* to *b*; it is used for finishing holes and the drill or rose reamer preceding it should leave the hole very close to the required size. These reamers are held while in use in a socket inserted in the tailstock spindle, as when using a twist drill.

Holding Work on Faceplate

Some castings or forgings are so shaped that they cannot be held in a chuck very well, or perhaps not at all, and work of this kind is often held by clamping it to the faceplate. An example of faceplate work is shown in Fig. 38, This is a rectangular cast-iron plate having a round boss or projection, the end *e* of which is to be turned parallel with the back face of the plate which was previously finished on a planer. A rough cored hole through the center of the boss also

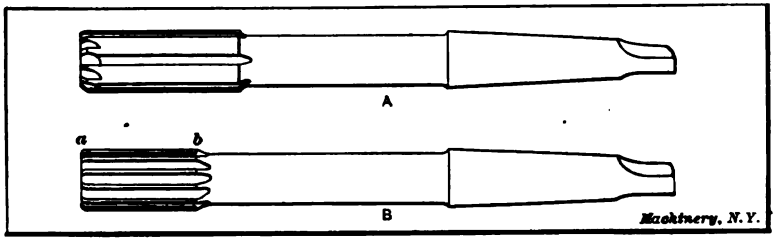


Fig. 37. Rose and Fluted Reamers

needs to be bored true. The best way to perform this operation in the lathe would be to clamp the finished surface of the casting directly against the faceplate by bolts and clamps *a*, *b*, *c*, and *d*, as shown; the work would then be turned just as though it were held in a chuck. By holding the casting in this way, face *e* will be finished parallel with the back surface because the latter is clamped directly against the true-running surface of the faceplate. If a casting of this shape were small enough it could also be held in the jaws of an independent chuck, but if the surface *e* needs to be exactly parallel with the back face, it is better to clamp the work to the faceplate. Most lathes have two faceplates: One of small diameter used principally for driving work turned between centers, and a large one for holding heavy or irregularly shaped pieces; either of these can be screwed on the spindle and the large faceplate has a number of slots through which clamping bolts can be inserted.

The proper way to clamp a piece to the faceplate depends, of course, largely on its shape and the location of the surface to be machined, but in any case it is necessary to hold it securely to prevent any shifting after a cut is started. Sometimes castings can be held by inserting bolts through previously drilled holes, but when clamps are

used in connection with the bolts, their outer ends are supported by hard wood or metal blocks which should be just high enough to make the clamp bear evenly on the work. When deep roughing cuts have to be taken, especially on large diameters, it is well to bolt a piece to the faceplate and against one side of the casting, as at *D*, to act as a driver and prevent the work from shifting; but a driver would not be needed in this particular case. Of course a faceplate driver is always placed to the rear, as determined by the direction of rotation, because the work tends to shift backward when a cut is being taken. If the surface which is clamped against the faceplate is finished as in this case, the work will be less likely to shift if a piece of paper is placed between it and the faceplate. Work mounted on the faceplate is generally set true by some surface before turning. As the hole in this casting should be true with the round boss, the casting is shifted on the faceplate until the rough outer surface of the boss runs true;

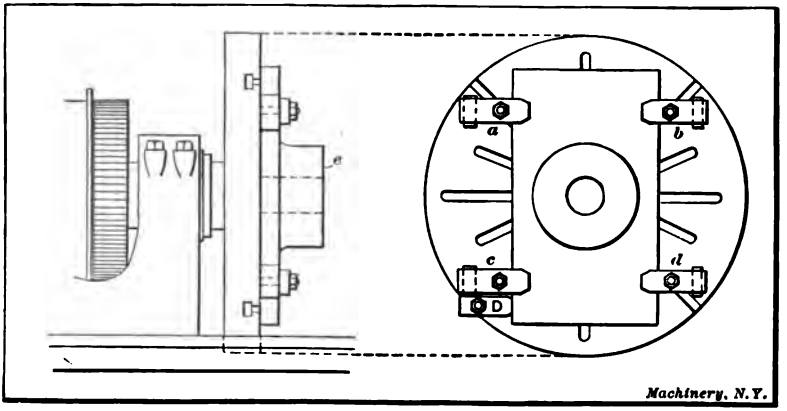


Fig. 38. Casting Clamped to Faceplate for Turning

the clamps which were previously set up lightly are then tightened. The face *e* is first turned by using a round-nosed tool. This tool is then replaced by a boring tool and the hole is finished to the required diameter. If the hole being bored is larger than the central hole in the faceplate, the casting should be clamped against parallel pieces, and not directly against the faceplate, to provide clearance for the tool when it reaches the inner end of the hole and prevent cutting the faceplate. The parallel pieces should be of the same thickness and be located near the clamps to prevent springing the casting.

Application of Angle-plate to Faceplate

Another example of faceplate work is shown in Fig. 39. This is a cast-iron elbow *E*, the two flanges of which are to be faced true and square with each other. The shape of this casting is such that it would be very difficult to clamp it directly to the faceplate, but it is easily held on an angle-plate *P*, which is bolted to the faceplate. The two surfaces of this angle-plate are square with each other so

that when one flange of the elbow is finished and bolted against the angle-plate, the other will be faced square. When setting up an angle-plate for work of this kind, the distance from its work-holding side to the center of the faceplate is made equal to the distance *d* between the center of one flange and the face of the other, so that the flange to be faced will run about true when bolted in place. As the angle-plate and work are almost entirely on one side of the faceplate, a weight *W* is attached to the opposite side for counterbalancing. Very often weights are also needed to counterbalance offset parts that are

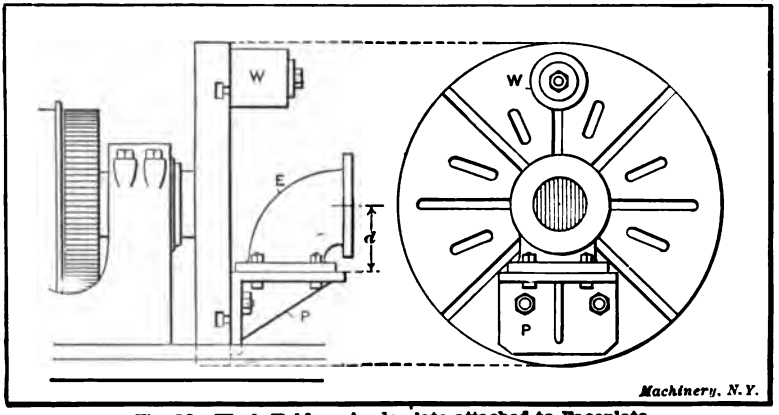


Fig. 39. Work Held on Angle-plate attached to Faceplate

bolted directly to the faceplate. Sometimes it is rather difficult to hold heavy pieces against the vertical surface of the faceplate while applying the clamps, and occasionally the faceplate is removed and placed in a horizontal position on the bench; the work can then be located about right, and after it is clamped, the faceplate is placed on the lathe spindle by the assistance of a crane.

Special faceplate jaws such as the one shown to the right in Fig. 27, can often be used to advantage for holding work on large faceplates. Three or four of these jaws are bolted to the faceplate which is converted into a kind of independent chuck. These faceplate jaws are especially useful for holding irregularly shaped parts as the different jaws can be located in any position.

CHAPTER VI

LATHE TURNING TOOLS

Notwithstanding the fact that a great variety of work can be done in the lathe, the number of turning tools required is comparatively small. Fig. 41 shows the forms of tools that are used principally, and typical examples of the application of these various tools are indicated in Fig. 42. The reference letters used in these two illustrations correspond for tools of the same type, and both views should be referred to in connection with the following description.

The tool shown at *A* is the form generally used for rough turning, that is for taking deep cuts when considerable metal has to be removed. At *B* a tool of the same type is shown, having a bent end which enables it to be used close up to a shoulder or surface *s* that might come in contact with the tool-rest if the straight form were employed. Tool *C*, which has a straight cutting end, is used on certain classes of work for taking light finishing cuts, with a coarse feed. As explained in Chapter V, this type of tool will leave a smooth finish even though

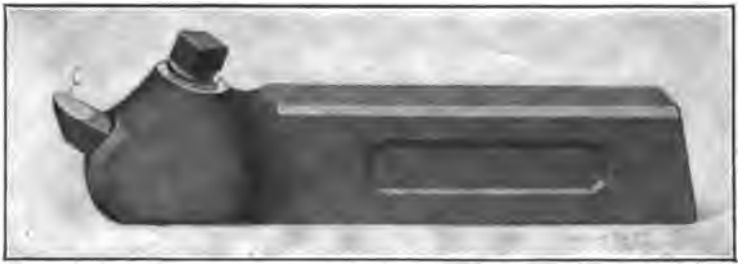


Fig. 40. Turning Tool with Inserted Cutter

the feed is coarse, provided the flat cutting edge is set parallel with the tool's travel so as to avoid ridges. Broad-nosed tools and wide feeds are better adapted for finishing cast iron than steel. When turning steel, if the work is at all flexible, a broad tool tends to gouge into it and for this reason round-nosed tools and finer feeds are generally necessary. A little experience in turning will teach more on this point than a whole chapter on the subject.

The side tools shown at *D* and *E* are for facing the ends of shafts, collars, etc. The first tool is known as a right-side tool because it operates on the right end or side of a shaft or collar, whereas the left-side tool *E* is used on the opposite side, as shown in Fig. 42. Side tools are also bent to the right or left because the cutting edge of a straight tool cannot always be located properly for facing certain surfaces. A bent right-side tool is shown at *F*. A form of tool that is frequently used is shown at *G;* this is known as a parting tool and is used for severing pieces and for cutting grooves, squaring corners, etc. The same type of tool having a bent end is shown at *H* (Fig.

42) severing a piece held in the chuck. Work that is held between centers should not be entirely severed with a parting tool unless a steady-rest is placed between the tool and faceplate, as otherwise the tool may be broken by the springing of the work just before the piece is cut in two. It should be noted that the sides of this tool slope inward

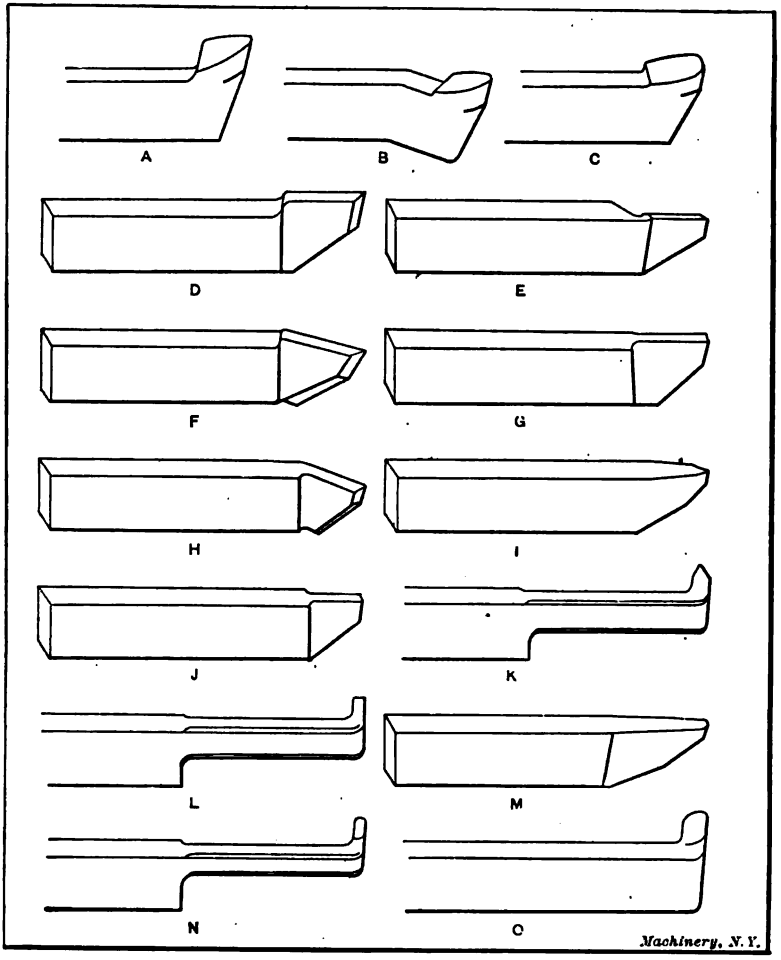


Fig. 41. Set of Lathe Turning Tools for General Work

back of the cutting edge to provide clearance when cutting in a narrow groove.

At *I* a thread tool is shown for cutting a U. S. standard thread. This thread is the form most commonly used in this country at the present time. A tool for cutting a square thread is shown at *J*. This is shaped very much like a parting tool except that the cutting

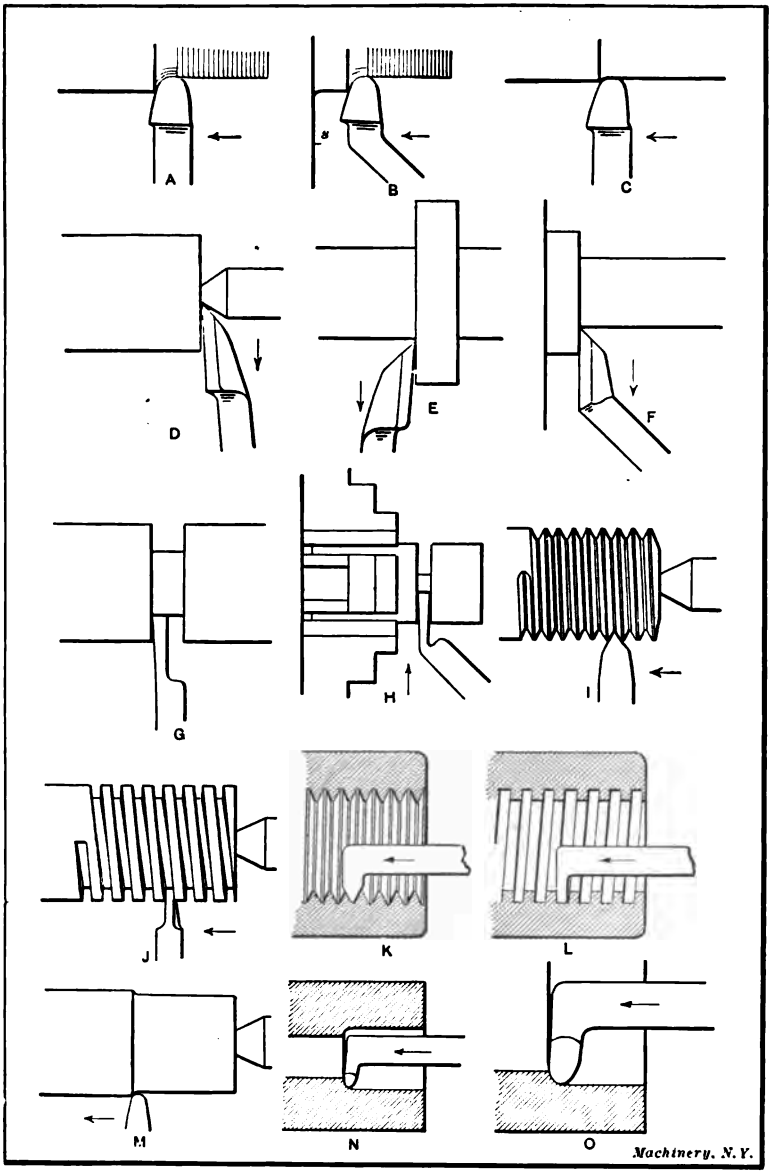


Fig. 42. Views Illustrating Use of Various Types of Lathe Tools

end is inclined slightly to correspond with the helix angle of the thread, as explained in Chapter IV, of MACHINERY'S Reference Book, No. 92, which contains descriptions of different thread forms and methods of cutting them. Internal thread tools are shown at *K* and *L*

for cutting U. S. standard and square threads in holes. It will be seen that these tools are somewhat like boring tools excepting the ends which are shaped to correspond with the thread which they are intended to cut.

A tool for turning brass is shown at *M*. Brass tools intended for general work are drawn out quite thin and they are given a narrow rounded point. The top of the brass tool is usually ground flat or without slope as otherwise it tends to gouge into the work, especially

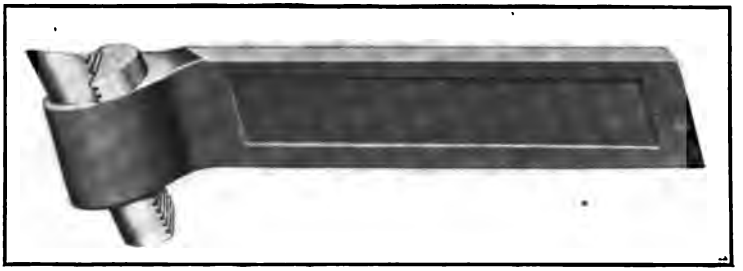


Fig. 43. Heavy Inserted-cutter Turning Tool

if the latter is at all flexible. The end of a brass tool is sometimes ground flat for turning large rigid work, such as brass pump linings, etc., so that a coarse feed can be used without leaving a rough surface. The tools at *N* and *O* are for boring or finishing drilled or cored holes. Two sizes are shown, which are intended for small and large holes, respectively.

The different tools referred to in the foregoing might be called the standard types because they are the ones generally used, and as Fig.

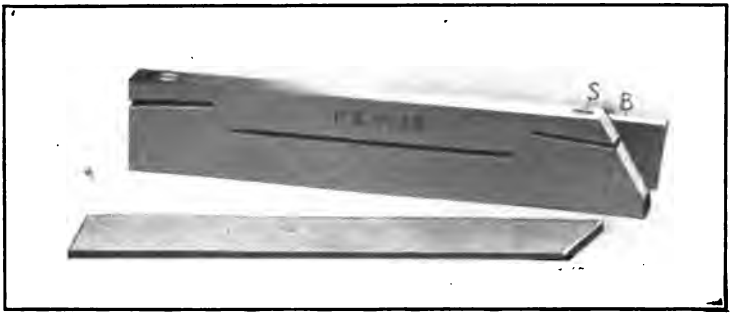


Fig. 44. Parting Tool with Inserted Blade

42 indicates, they make it possible to turn an almost endless variety of forms. Occasionally some special form of tool is needed for doing odd jobs, having, perhaps, an end bent differently or a cutting edge shaped to some particular form. Tools of the latter type, which are known as "form tools," are sometimes used for finishing surfaces that are either convex, concave, or irregular in shape. The cutting edges of these tools are carefully filed or ground to the required shape, and

the form given the tool is reproduced in the part turned. Ornamental or other irregular surfaces can be finished very neatly by the use of such tools. It is very difficult, of course, to turn convex or concave surfaces with a regular tool; in fact, it would not be possible to form a true spherical surface, for instance, without special equipment, because the tool could not be moved along a true curve by simply using the longitudinal and cross feeds. Form tools should be sharpened by

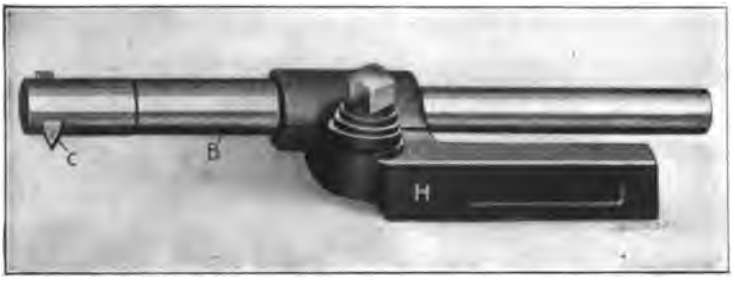


Fig. 45. Boring Tool with Inserted Cutter and Adjustable Bar

grinding entirely on the top surface, as any grinding on the end or flank would alter the shape of the tool.

Tool-holders with Inserted Cutters

All of the tools shown in Fig. 41 are forged from the bar, and when the cutting ends have been ground down considerably it is necessary to forge a new end. To eliminate the expense of this continual dressing of tools and also to effect a great reduction in the amount of tool

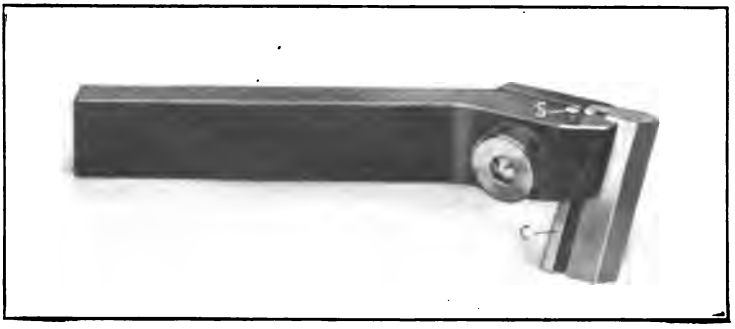


Fig. 46. Threading Tool

steel required, tool-holders having small inserted cutters are used in many shops.

A tool-holder of this type for outside turning is shown in Fig. 40. The cutter *C* is held in a fixed position by the set-screw shown, and it is sharpened, principally, by grinding the end, except when it is desired to give the top of the cutter a different slope from that due to its angular position. Another inserted-cutter turning tool is shown in Fig. 43, which is a heavy type intended for roughing. The cutter in

this case, has teeth on the rear side engaging with corresponding teeth cut in the clamping block which is tightened by a set-screw on the side opposite that shown. With this arrangement, the cutter can be adjusted upward as the top is ground away.

A parting tool of the inserted blade type is shown in Fig. 44. The blade *B* is clamped by screw *S* and also by the spring of the holder when the latter is clamped in the tool-post. The blade can, of course, be moved outward when necessary. Fig. 45 shows a boring tool consisting of a holder *H*, a bar *B* that can be clamped in any position, and an inserted cutter *c*. With this type of boring tool, the bar can be extended beyond the holder just far enough to reach through the hole to be bored, which makes the tool very rigid. A thread tool of the holder type is shown in Fig. 46. The angular edge of the cutter *C* is accurately ground by the manufacturers, so that the tool is sharpened by simply grinding it flat on the top. As the top is ground away, the cutter is raised by turning screw *S* which can also be used for setting the tool to the proper height.

CHAPTER VII

STEADY- AND FOLLOW-RESTS

Occasionally long slender shafts, rods, etc., which have to be turned, are so flexible that it is necessary to support them at some point between the lathe centers. An attachment for the lathe known as a steadyrest is often used for this purpose. A steadyrest is composed of a frame containing three jaws *J* (Fig. 47), that can be adjusted in or out radially by turning screws *S*. The frame is hinged at *h*, thus allowing the upper half to be swung back (as shown by the dotted lines) for inserting or removing the work. The bolt-clamp *c* holds the hinged part in the closed position. The base of the frame has

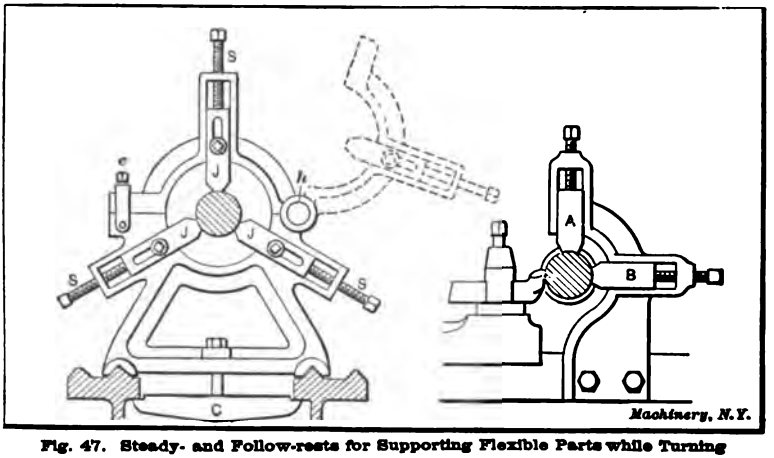


Fig. 47. Steady- and Follow-rests for Supporting Flexible Parts while Turning

V-grooves in it that fit the ways of the lathe bed. When the steadyrest is in use, it is secured to the bed by clamp *C*, and the jaws *J* are set in against the work, thus supporting or steadying it during the turning operation. The steadyrest must, of course, be located at a point where it will not interfere with the turning tool.

Supporting Flexible Work with a Steadyrest

Fig. 48 shows the application of the steadyrest to a long forged rod, having one small end, which makes it too flexible to be turned without support. As this forging is rough, a true surface *n* a little wider than the jaws *J* (Fig. 47) is first turned as a bearing for the jaws. This should be done very carefully to prevent the work from mounting the tool. A sharp pointed tool should be used and very light cuts taken. The steadyrest is next clamped to the lathe bed opposite the turned surface, and the jaws are adjusted in against the work, thus forming a kind of bearing. Care should be taken not to

set up the jaws too tight as the work should turn freely but without play. The large part of the rod and central collar are then turned to size, this half being machined while the small part is in the rough and as stiff as possible. The rod is then reversed and the steady-rest is applied to the part just finished, as shown at *B*, thus supporting

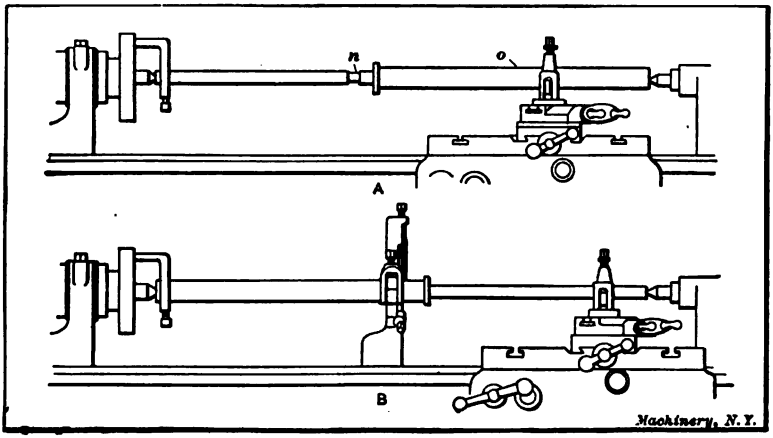


Fig. 48. Application of Steadyrest

the work while the small end is being turned. That part against which the jaws bear should be kept well oiled and if the surface is finished, it should be protected by placing a strip of emery cloth beneath the jaws with the emery side out; a strip of belt leather is also used for this purpose, the object in each case being to prevent the jaws from scratching and marring the finished surface, as they tend to do, especially if at all rough.

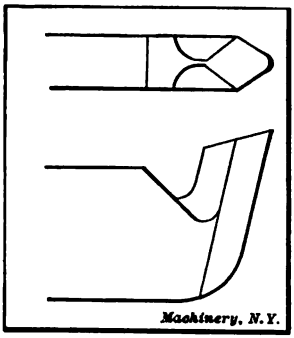


Fig. 49. Diamond-point Turning Tool

If the work were too flexible to permit turning a spot at *n*, this could be done by first "spotting" it at some point *o*, and placing the steady-rest at that point while turning another spot at *n*. The tool shown in Fig. 49 is a good form to use for work of this kind because of its narrow point. This is known as a "diamond point," and is frequently used for light turning. The shape of this tool is clearly shown in the illustration. The V-shaped cutting edge is usually rounded slightly at the point, and the top slopes backward from the cutting edge, as shown.

Sometimes it is desirable to apply a steady-rest to a surface that does not run true and one which is not to be turned; in such a case a device called a "cat-head" is used. This is simply a sleeve *S* (Fig. 51) which is placed over the untrue surface to serve as a bearing for

the steadyrest. The sleeve is made to run true by adjusting the four set-screws at each end, and the jaws of the steadyrest are set against it, thus supporting the work.

Application of Steadyrest when Boring—Use of "Bridles" or "Hold-backs"

Another example illustrating the use of the steadyrest is shown in Fig. 50. The rod *R* is turned on the outside and a hole is to be bored in the end (as shown by dotted lines) true with the outer surface. If the centers used for turning the rod are still in the ends, as they would be ordinarily, this work could be done very accurately by the following method: The rod is first placed between the centers as for turning, with a driving dog *D* attached, and the steady-rest jaws *J* are set against it near the outer end, as shown.

Before any machine work is done, means must be provided for holding

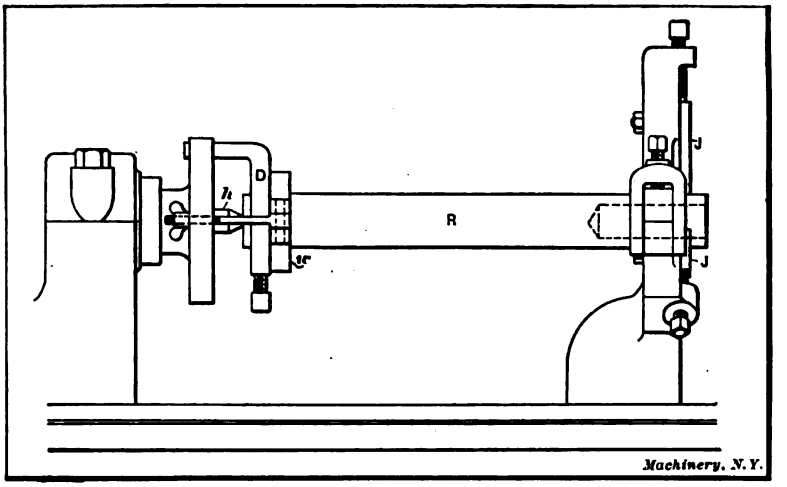


Fig. 50. Shaft supported by Steadyrest for Drilling and Boring End

the rod back against the headstock center *h*, because, for an operation of this kind, the outer end cannot be supported by the tailstock center; consequently the work tends to shift to the right. One method of accomplishing this is shown in the illustration. A hard-wood piece *w*, having a hole somewhat larger than the work, is clamped against the dog, in a crosswise position, by the swinging bolts and thumb-screws shown. If the dog is not square with the work, the wood piece should be canted so that the bearing will not be all on one side. For large heavy parts a similar "bridle" or "hold-back"—as this is commonly called—is made by using steel instead of wood for the part *w*. Another very common method which requires no special equipment is illustrated in Fig. 52. Ordinary leather belt lacing *L* is attached to the work and faceplate while the latter is screwed off a few turns as shown. Then the lacing is drawn up by hand and tied, and the faceplate is screwed on the spindle, thus tightening the lacing and drawing the

work against the headstock center. The method of applying the lacing is quite clearly indicated in the illustration. If a small driving faceplate is used, it may be necessary to drill holes for the belt lacing, as shown.

A hole is next drilled in the end of the rod by using a twist drill and the tailstock, as explained in connection with Fig. 34, Chapter V. If the hole is finished by boring, a depth mark should be made on the

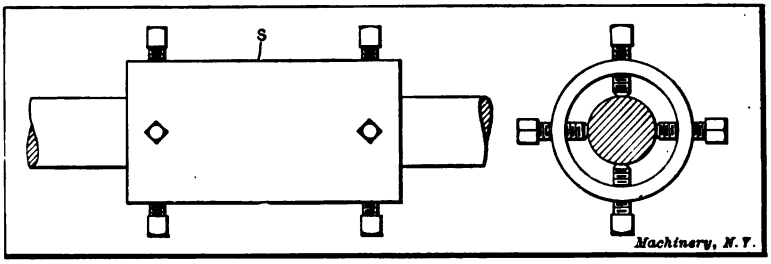


Fig. 51. Cat-head which is sometimes used as Bearing for Steadyrest

tool shank that will warn the workman of the cutting end's approach to the bottom. A chuck can also be used in connection with a steady-rest for doing work of this kind as shown in Fig. 53, the end of the rod being held and driven by the chuck *C*. If the work is centered, it can be held on these centers while setting the steadyrest and adjusting the chuck, but if the ends are without centers, a very good way is to make light centers in the ends with a punch; after these are properly

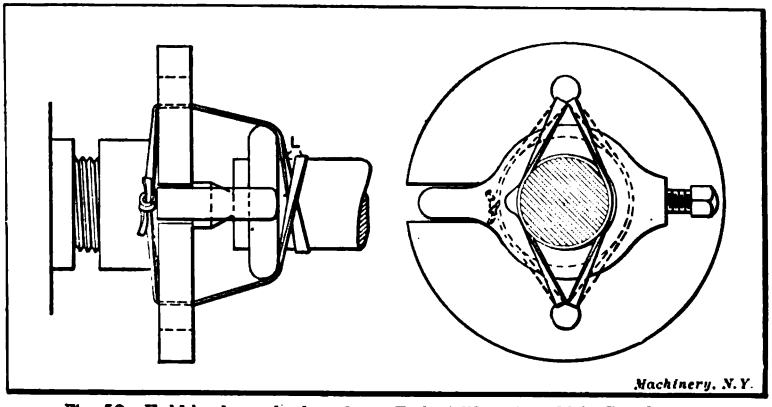


Fig. 52. Hold-back used when Outer End of Work is held in Steadyrest

located they are used for holding the work until the steadyrest and chuck jaws have been adjusted. In case it is necessary to have the end hole very accurate with the outside of the finished rod, a test indicator *I* should be applied to the shaft as shown. This is an instrument which shows with great accuracy whether a rotating part runs true and it is also used for many other purposes in machine shops. The indicator is held in the lathe toolpost and the contact point

beneath the dial is brought against the work. If the latter does not run true, the hand of the indicator vibrates and the graduations on the dial show how much the work is out in thousandths of an inch.

The Follow-rest

For certain classes of long slender work, such as shafts, etc., a follow-rest is often used for supporting the work while turning. The follow-rest differs from the steadyrest in that it is attached to and travels with the lathe carriage. The type illustrated to the right in

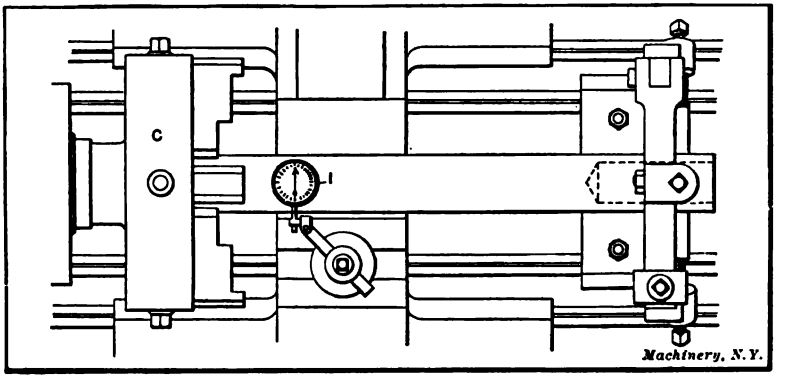


Fig. 53. Testing Work with Dial Indicator

Fig 47 has two adjustable jaws which are located nearly opposite the turning tool, thus providing support where it is most needed. In using this rest, a cut is started at the end and the jaws are adjusted to this turned part. The tool is then fed across the shaft, which cannot spring away from the cut because of the supporting jaws. Some follow-rests have, instead of jaws, a bushing bored to fit the diameter being turned, different bushings being used for different diameters. The bushing forms a bearing for the work and holds it rigidly. Whether a bushing or jaws are used, the tool is slightly in advance of the supporting member.

CHAPTER VIII

HOW TO CUT A THREAD IN A LATHE

When threads are cut in the lathe a tool *t* is used (see Fig. 55), having a point corresponding to the shape of the thread, and the carriage is moved along the bed a certain distance for each revolution of the work (the distance depending on the number of threads to the inch being cut) by the lead-screw *S* which is rotated by gears *a*, *b* and *c*, which receive their motion from the spindle. As the rate of the carriage travel per revolution of the work, and, consequently, the number of threads per inch that is cut, depends on the size of the gears *a* and *c* (called change gears) the latter have to be changed for cutting different threads. The proper change gears to use for cutting a given number of threads to the inch, is ordinarily determined

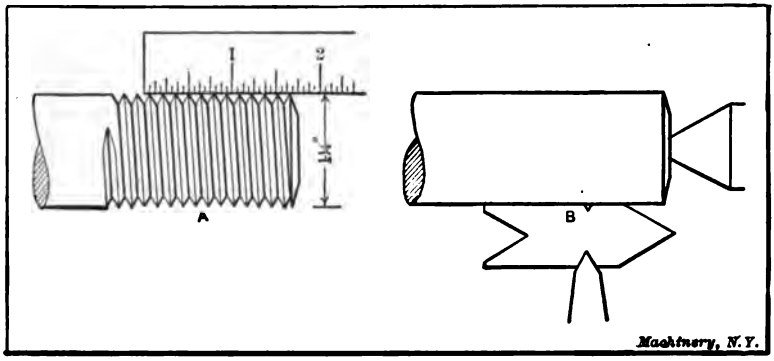


Fig. 54. Measuring Number of Threads per Inch—Setting Thread Tool

by referring to a table or "index plate" *I* which shows what the size of gears *a* and *c* should be, or the number of teeth each should have, for cutting any given number of threads per inch.

Selecting the Change Gears

Suppose a V-thread is to be cut on the end of the bolt *B*, having a diameter of 1¼ inch and seven threads per inch of length, as shown at *A* in Fig. 54, which is a standard number for that diameter. First the change gears to use are found on plate *I* which is shown enlarged in Fig. 56. This plate has three columns: The first contains different numbers of threads to the inch, the second the size gear to place on the "spindle" or "stud" at *a* for different threads, and the third the size of gear *c* for the lead-screw. As the thread selected as an example has seven threads per inch, gear *a* should have 48 teeth, this being the number given in the second column opposite figure 7 in the first. By referring to the last column, we find that the lead-screw gear should

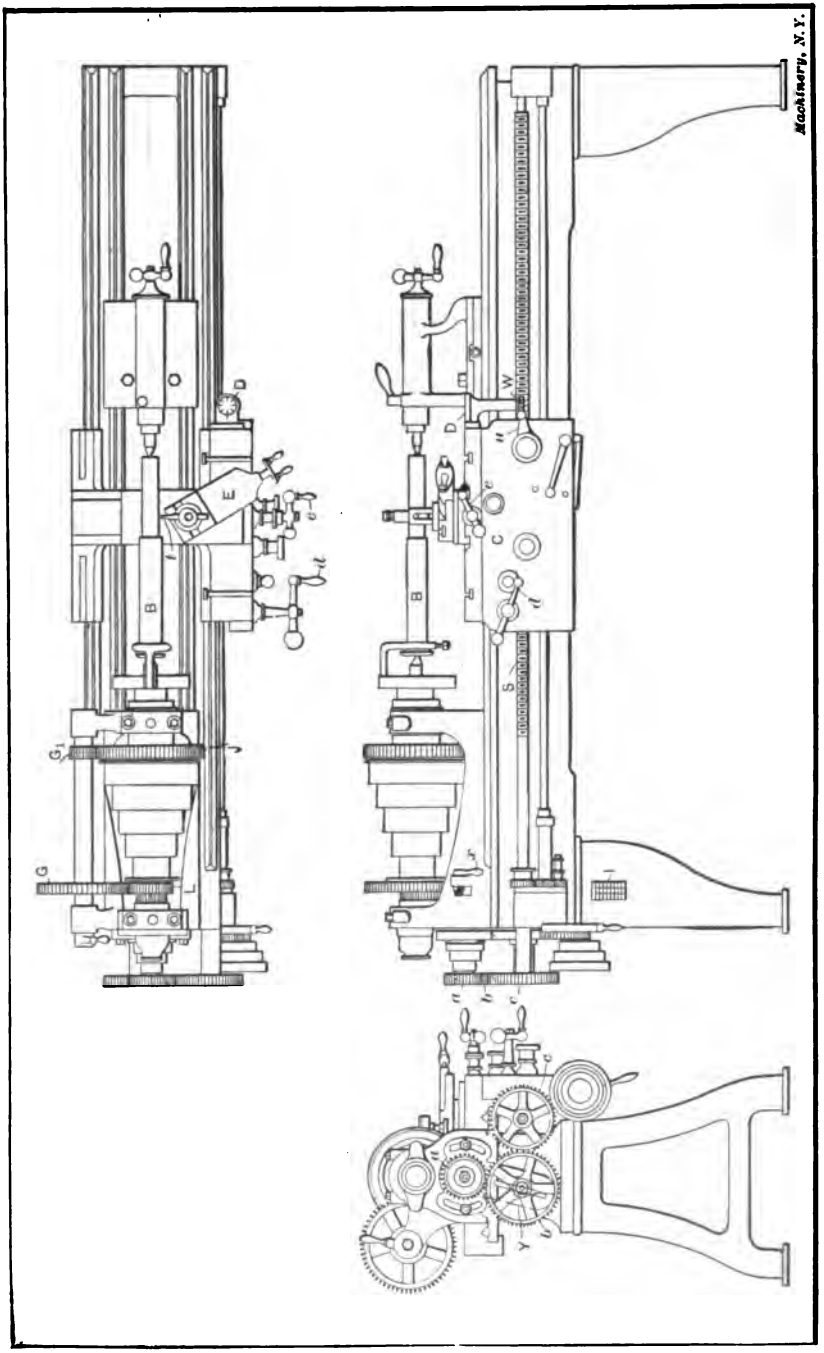


Fig. 55. Plan and Elevations of Engine Lathe

have 84 teeth. These gears are selected from an assortment provided with the lathe and they are placed on the spindle and lead-screw, respectively. Intermediate gear *b* does not need to be changed as it is simply an "idler" for connecting gears *a* and *c*. Gear *b* is mounted on a swinging yoke *Y* so that it can be adjusted to mesh properly with different gear combinations; after this adjustment is made, the lathe is geared for cutting seven threads to the inch. (The change gears of many modern lathes are so arranged that different combinations are obtained by simply shifting a lever. A lathe having this quick-change gear mechanism is described in Chapter VI of MACHINERY'S Reference Book No. 92.) The work *B* is then placed between the centers just as it would be for turning, with the end to be threaded turned to a diameter of 1¼ inch, which is the outside diameter of the the thread.

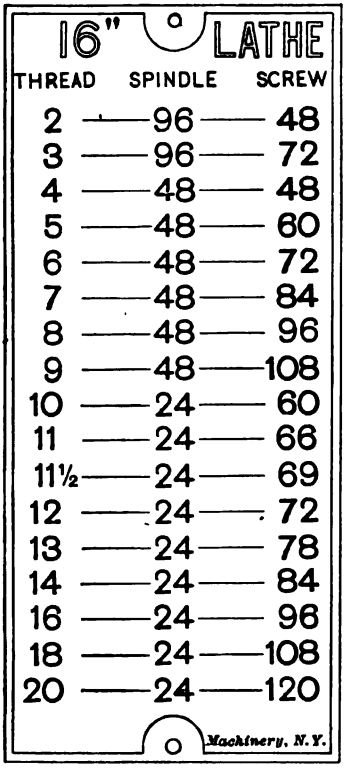


Fig. 56. Index Plate showing Gear Changes for Threading

The Thread Tool

The form of tool used for cutting a V-thread is shown at *A*, Fig. 57. The end is ground V-shaped and to an angle of 60 degrees, which corresponds to the angle of a standard V-thread. The front or flank *f* of the tool is ground back to an angle to provide clearance, but the top is left flat or without slope. As it is very important to grind the end to exactly 60 degrees, a gage *G* is used, having 60-degree notches to which the tool-point is fitted. The tool is clamped in the toolpost as shown in the plan view, Fig. 55, square with the work, so that both sides of the thread will be cut to the same angle with the axis of the work. A very convenient way to set a thread tool square is illustrated at *B*, Fig. 54. The thread gage is placed against the part to be threaded, as shown, and the tool is adjusted until the angular sides of the point bear evenly in the 60-degree notch of the gage. The top of the tool point should also be at the same height as the lathe centers, as otherwise the angle of the thread will not be correct.

Cutting the Thread

The lathe is now ready for cutting the thread. This is done by taking several cuts, as indicated at *A*, *B*, *C* and *D* in Fig. 58, the tool being fed in a little farther for each successive cut until the

thread is finished. When these cuts are being taken, the carriage is moved along the bed as previously explained, by the lead-screw *S*, Fig. 55. The carriage is engaged with the lead-screw by turning lever *u* which causes the halves of a split nut to close around the screw. The way a lathe is handled when cutting a thread is as follows: After the lathe is started, the carriage is moved until the tool-point is slightly beyond the right end of the work, and the tool is fed in far enough to take the first cut. The carriage is then engaged with the lead-screw, by operating lever *u*, and the tool moves to the left (in this case 1/7 inch for each revolution of the work) and cuts

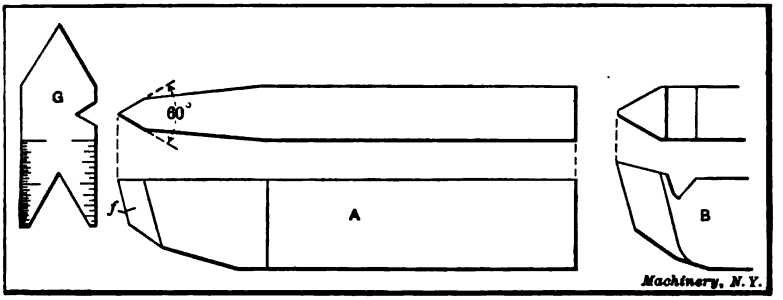


Fig. 57. Thread Tools and Gage for Testing Angle of End

a winding groove as at *A*, Fig. 58. When the tool has moved as far as the thread is wanted, it is withdrawn by a quick turn of handle *e*, and the carriage returned to the starting point for another cut. The tool is then fed in a little farther and a second cut is taken as at *B*, and this operation is repeated as at *C* and *D* until a "full" thread is cut or until the top of the thread is sharp. The thread is then tested for size, but before referring to this part of the work, the way the carriage is returned to the starting point after each cut, should be explained.

When the tool is withdrawn at the end of the first cut, if the carriage is disengaged from the lead-screw and returned by hand, the tool may or may not follow the first cut when the carriage is again engaged with the lead-screw. If the number of threads to the inch being cut is a multiple of the number on the lead-screw *S*, then the carriage can be returned by hand and engaged with the lead-screw at random and the tool will follow the first cut. For example, if the lead-screw has six threads per inch, and 6, 12, 18 or any number of threads is being cut that is a multiple of six, the carriage can be engaged at any time and the tool will always follow the original cut. This is not the case, however, when the number of threads being cut is not a multiple of the number on the lead-screw. One method of bringing the carriage back to the starting point when cutting threads which are not multiples, is to reverse the lathe (by shifting the overhead driving belts) in order to bring the tool back to the starting point without disengaging the carriage; in this way the tool is kept in the same relation to the work, and the carriage is

not disengaged from the lead-screw until the thread is finished. This is a good method when cutting short threads having a length of say two or three inches; but when they are longer, and especially when the diameter is comparatively large (which means a slower speed), it is rather slow as considerable time is wasted while the tool is moving back to its starting point. This is due to the fact that the carriage is moved slowly by the lead-screw, but when disengaged, it can be traversed quickly by turning handle *d*, Fig. 55.

A method of returning the carriage by hand when the number of threads being cut is not a multiple of the number on the lead-screw is as follows: The tool is moved a little beyond the right end of the work and the carriage is engaged. The lathe is then turned forward by hand to take up any lost motion, and a line is made on the lathe bed showing the position of the carriage. The positions of the spindle and lead-screw are also marked by chalking a tooth on both

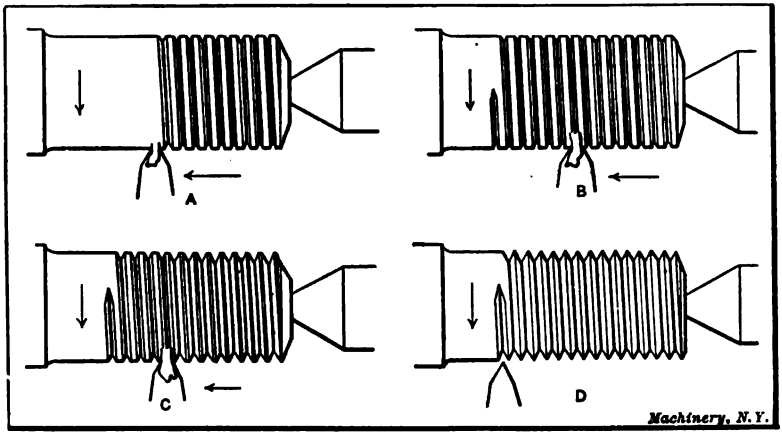


Fig. 58. Thread is formed by taking a number of Successive Cuts

the spindle and lead-screw gears, which happens to be opposite a corner or other point on the bed. After a cut is taken, the carriage is returned by hand to the original starting point as shown by the line on the bed, and is again engaged when the chalk marks show that the spindle and lead-screw are in their original position; the tool will then follow the first cut. If the body of the tailstock is moved against the bridge of the carriage before starting the first cut, the carriage can be located for each following cut by moving it back against the tailstock, and it will not be necessay to have a line on the bed.

Indicator or Chasing Dial for Catching Threads

On some lathes there is an indicator for "catching threads," as this is called in shop language. This is a simple device attached to the carriage and consists of a graduated dial *D* and a worm-wheel *W* (see Figs. 55 and 59) which meshes with the lead-screw, so that the dial is revolved by the lead-screw when the carriage is stationary, and when the carriage is moved by the screw, the dial remains stationary.

The indicator is used by engaging the carriage when one of the graduation lines is opposite the arrow mark; after a cut is taken the carriage is returned by hand and when one of the graduation lines again moves opposite the arrow, the half-nuts are thrown into mesh, as before, and this is repeated for each successive cut, thus causing the tool to always come right with the thread. If the number of threads per inch is even, engagement can be made when any line is opposite the arrow, but for odd numbers such as 3, 7, 9, 11, etc., one of the four long or numbered lines must be used. Of course, if the thread being cut is a multiple of the number on the lead-screw, engagement can be made at any time.

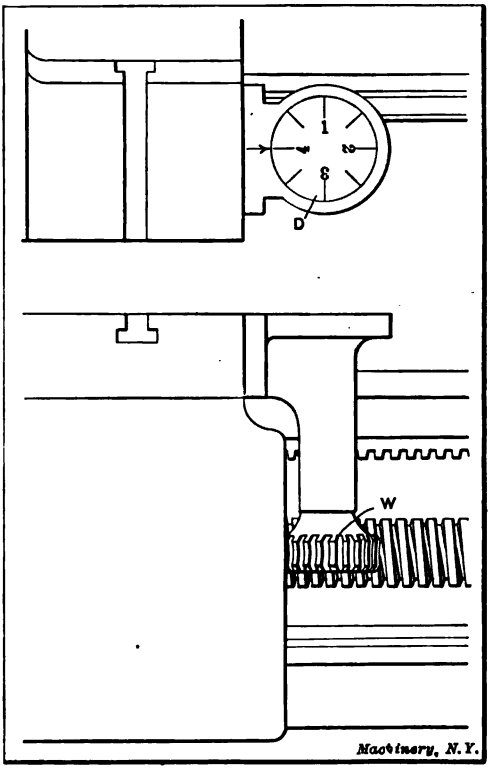


Fig. 59. Indicator used when Cutting Threads

Having considered the use of the indicator, its principle will be explained. The number of teeth in worm-wheel *W* is some multiple of the number of threads per inch of the lead-screw, and the number of teeth in the wheel, divided by the pitch of the screw, equals the number of graduations on the dial. For example, if the lead-screw has six threads per inch, the worm-wheel could have twenty-four teeth, in which case the dial would have four divisions, each representing an inch of carriage travel, and by sub-dividing the dial into eighths (as shown) each line would correspond to ½ inch of travel. The dial, therefore, would enable the carriage to be engaged with the lead-screw at points equal to a travel of one-half inch. To illustrate the advantage of this, suppose ten threads per inch are being cut and (with the lathe stationary) the carriage is disengaged and moved 1/6 inch or one thread on the lead-screw; the tool point will also have moved 1/6 inch, but it will not be opposite the next thread groove in the work as the pitch is 1/10 inch. If the carriage is moved another thread on the lead-screw, or 2/6 inch, the tool will still be out of line with the thread on the work, but when it has moved three threads, or

½ inch, the tool will then coincide with the original cut because it has passed over exactly five threads. This would be true for any number of threads per inch that is divisible by 2. If the thread being cut had nine threads per inch, or any other odd number, the tool would only coincide with the thread at points 1 inch apart. Therefore, the carriage can only be engaged when one of the four graduations representing an inch of travel is opposite the arrow, when cutting odd threads; whereas even numbers can be "caught" by using any one of the eight lines.

This indicator can also be used for "catching" fractional threads. As an illustration, suppose 11½ threads per inch are being cut, and the carriage is engaged the first time when graduation line 1 is opposite the arrow; engagement would then be made for each successive cut, when either line 1 or 3 were opposite the arrow, or in other words

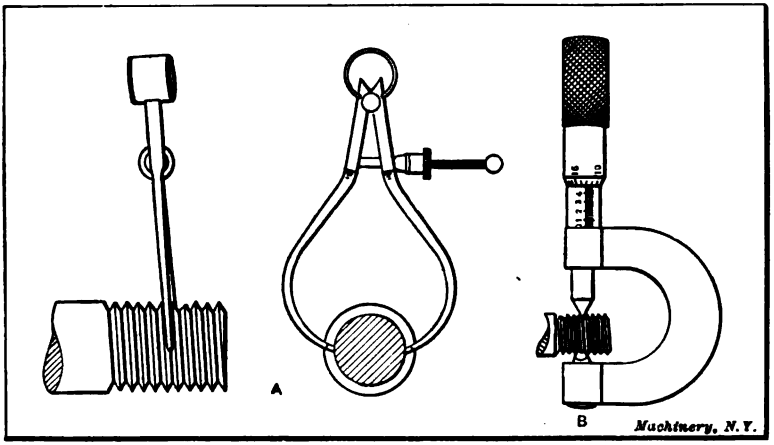


Fig. 60. Testing Diameter of Thread with Calipers and Micrometer

at spaces equal to a carriage movement of 2 inches. As the use of the indicator when cutting fractional threads is liable to result in error, it is better to keep the half-nuts in engagement and return the carriage by reversing the lathe.

Testing the Size of the Thread

When the thread tool has been fed in far enough to form a complete thread as at *D*, Fig. 58, the thread is then tested for size. If we assume that the bolt is being threaded for a standard 1¼ nut, it would be removed from the lathe and the test made by screwing a nut on the end. If the thread were too large, the nut might screw on very tightly or not at all; in either case, the work would again be placed in the lathe and a light cut taken over it to reduce the thread to the proper size. When replacing a threaded part between the centers, it should be put back in the original position, that is, with the tail of the driving dog in the same slot of the faceplate previously occupied. As it is difficult to tell just when a thread is cut to the

exact size, special thread calipers having wedge-shaped ends are sometimes used for measuring the diameter of the thread at the bottom of the grooves, or the root diameter, as shown at *A*, Fig. 60. These calipers can be set from a tap corresponding to the size of the thread being cut, or from a previously threaded piece of the right size. Another form of caliper for testing threads is shown at *B*. This is one of the micrometer type and is intended for very accurate work. The spindle of this micrometer has a conical end and the "anvil" is

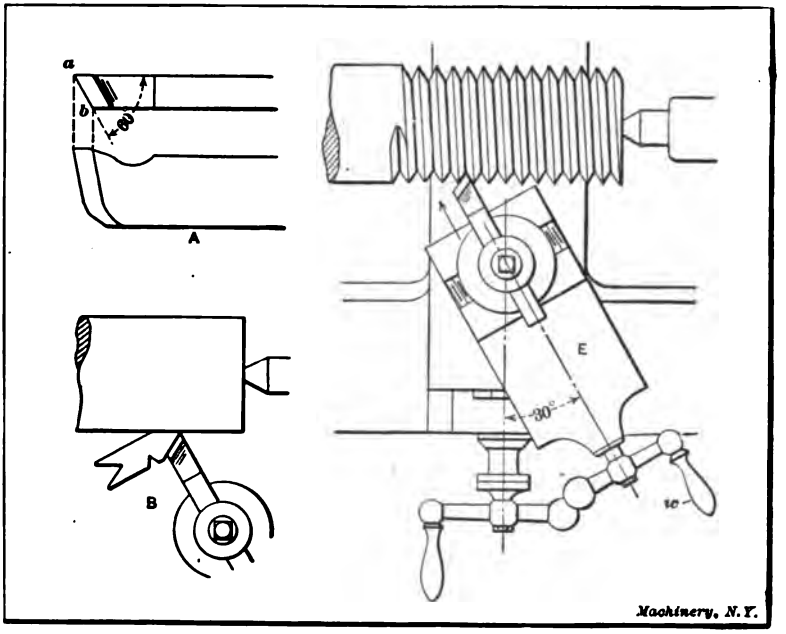


Fig. 61. Cutting Thread by using Compound Rest

V-shaped, and these ends bear on the sides of the thread or the surfaces which form the bearing when the screw is inserted in a nut or threaded hole.

Replacing Sharpened Tool—Tool for Roughing

If it is necessary to sharpen the thread tool before the thread is finished, it should be re-set square with the work by testing with the thread gage as at *B*, Fig. 54. The carriage is then engaged with the lead-screw and the lathe is turned forward to bring the tool opposite the partly finished thread and also to take up any backlash or lost motion in the gears or half-nut. If the tool-point is not in line with the thread groove previously cut, it can be shifted sidewise by feeding the compound rest *E* in or out, provided the latter is set in an angular position as shown in the plan view, Fig. 55.

If the thread tool is ground flat on the top as at *A*, Fig. 57, it is not a good tool for removing metal rapidly as neither of its two cutting edges has any slope. In order to give each cutting edge a backward

slope, it would be necessary to grind the top surface hollow or concave, which would be impracticable. When a coarse thread is to be cut, a tool shaped as at *B* can be used to advantage for rough turning the thread groove, which is afterward finished to the correct depth and angle by tool *A*. This roughing tool is ground with a backward slope from the point and the latter is rounded to make it stronger.

Use of Compound Rest for Thread Cutting

Another form of thread tool is shown at *A*, Fig. 61, which is very good, especially for cutting coarse threads. When this tool is used, the compound rest *E* is set to an angle of 30 degrees, as shown, and it is fed in for the successive cuts by handle *w* in the direction indicated by the arrow. It will be seen that the point *a* of the tool moves at an angle of 60 degrees with the axis of the work, thus forming one side of the thread, and the cutting edge *a*—*b*, which can be set as shown at *B*, forms the opposite side and does all the cutting. As this edge is given a backward slope, as shown, it cuts easily and enables threading operations to be performed quickly. Threads cut in this way are often finished by taking a light cut with a regular thread tool. The cutting edge *a*—*b* is ground to an angle of 60 degrees (or slightly less, if anything) with the side, as shown by the top view.

All the threads that have been illustrated in connection with the foregoing description have been of the simple V-form. There are, however, several other forms of threads in use and these various threads and the way in which they are cut is explained in Chapter IV of MACHINERY'S Reference Book No. 92.

When cutting threads in steel or wrought iron, some sort of lubricant is usually applied to the tool to preserve the cutting end and give a smooth finish to the thread. Sperm or lard oil is commonly used for this purpose. If the thread is small, the lubricant may be applied from an ordinary oil can, but when cutting comparatively large threads, it is better to have a stream of oil constantly playing upon the tool-point. This constant flow may be obtained by mounting a can having a spout leading to the tool on a bracket at the rear of the carriage.

It should be mentioned in this connection that cooling compounds are also used on regular turning tools cutting steel or wrought iron. Cast iron and brass are machined dry. A compound that is widely used is composed of water in which a quantity of sal soda has been dissolved. The use of cooling water permits higher cutting speeds, and gives a smoother finish, known as a "water" finish. To secure the best results, a rather large flow of soda water should be applied continuously on the chip at the point where it is being severed by the tool.

CHAPTER IX

CALCULATING CHANGE GEARS FOR THREAD CUTTING

As explained in Chapter VIII, the change gears for cutting threads of various pitches are shown by a table attached to the lathe. The proper gears to be used can be calculated, but the use of the table saves time and tends to avoid mistakes. Every machinist, however, should know how to determine the size of gears used for cutting any number of threads to the inch, but before referring to any rules, let us first consider why a lathe cuts a certain number of threads to the inch and how this number is changed by the use of different gears.

As the carriage *C* and the tool are moved by the lead-screw *S*, Fig. 55, which is geared to the spindle, the number of threads to the inch that are cut depends, in every case, on the number of turns the work makes while the lead-screw is moving the carriage one inch. If the lead-screw has six threads per inch, it will make six revolutions while the carriage and the thread tool travel one inch along the piece to be threaded. Now if the change gears *a* and *c* are so proportioned that the spindle makes the same number of revolutions as the lead-screw, in a given time, it is evident that the tool will cut six threads per inch. If the spindle revolved twice as fast as the lead-screw, it would make twelve turns while the tool moved one inch, and consequently twelve threads per inch would be cut; but to get this difference in speeds it is necessary to use a combination of gearing that will cause the lead-screw to revolve once while the lathe spindle and work make two revolutions.

Suppose that nine threads to the inch are to be cut and the lead-screw has six threads per inch. In this case the work must make nine revolutions while the lead-screw makes six and causes the carriage and thread tool to move one inch, or in other words, one revolution of the lead-screw corresponds to one and one-half revolution of the spindle; therefore, if the lead-screw gear has 36 teeth, the gear on the spindle stud should have only 24 teeth. The spindle stud will then revolve one and one-half times faster than the lead-screw, provided it rotates at the same rate of speed as the main lathe spindle. The number of teeth in the change gears that is required for a certain pitch, can be found by multiplying the number of threads per inch of the lead-screw, and the number of threads per inch to be cut, by the same multiplier. The formula which expresses the relation between threads per inch of lead screw, threads per inch to be cut, and the number of teeth in the change gears, is as follows:

$$\frac{\text{threads per inch of lead-screw}}{\text{threads per inch to be cut}} = \frac{\text{teeth in gear on spindle stud}}{\text{teeth in gear on lead-screw}}$$

Applying this to the example given, we have $\frac{6}{9} = \frac{24}{36}$ The values of 36 and 24 are obtained by multiplying 6 and 9, respectively, by 4, which,

of course, does not change the proportion. Any other number could be used as a multiplier, and if gears having 24 and 36 teeth were not available, this might be necessary. For example, if there were no gears of this size, some other multiplier as 5 or 6 might be used.

A general rule for finding change gears by this method would be as follows: Place the number of threads in the lead-screw in the numerator and the number to be cut in the denominator and then multiply both numerator and denominator by some number, until numbers are obtained which correspond to the numbers of teeth in gears that are available. The number obtained by multiplying the numerator represents the gear for the spindle stud, and the number obtained by multiplying the denominator, the gear for the lead-screw. As an example, suppose the number of teeth in the change gears supplied with the lathe are 24, 28, 32, 36, etc., increasing by four teeth up to 100, and assume that the lead-screw has six threads per inch and that ten threads per inch are to be cut. Then,

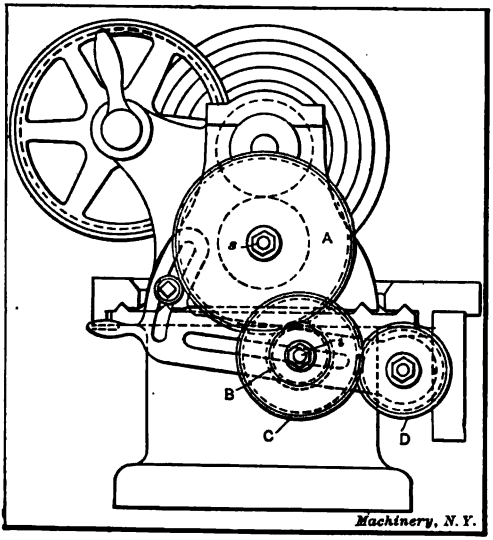


Fig. 62. Lathe having Compound Gears

$$\frac{6}{10} = \frac{6 \times 4}{10 \times 4} = \frac{24}{40}$$

By multiplying both numerator and denominator by 4, we obtain two available gears having 24 and 40 teeth, respectively. The 24-tooth gear goes on the spindle stud and the 40-tooth gear on the lead-screw. The number of teeth in the intermediate gear *b* which connects the stud and lead screw gears, is of no consequence.

We have assumed in the foregoing that the spindle stud (on which gear *a* is mounted) and the spindle made the same number of revolutions. In some lathes, however, these two members do not rotate at the same speed, so that if equal gears were placed on the lead-screw and spindle stud, the spindle would not make the same number of revolutions as the lead-screw. A very convenient way to determine the gears to use in such a case is as follows: First find the number of threads per inch cut when gears of the same size are placed on the lead-screw and spindle, either by actual trial or by referring to the index plate. Then use this number as the numerator instead of the actual number of threads per inch in the lead-screw, and proceed as previously described.

Change Gears for Lathes with Compound Gearing

When gearing is arranged as shown in Fig. 55, it is referred to as simple gearing, but sometimes it is necessary to introduce two gears (*B* and *C*) between the stud and screw as in Fig. 62, which is termed compound gearing. The method of figuring compound gearing is practically the same as that for simple gearing, except that the numerator and denominator are divided into two factors, each of which is multiplied by the same number to obtain the number of teeth in the change gears, as before.

Suppose the lathe has a lead-screw with six threads per inch and that the numbers of teeth in the gears available are 30, 35, 40 and so on, increasing by 5 up to 100. If for example, 24 threads per inch are to be cut, 6 is placed in the numerator and 24 in the denominator as before. The numerator and denominator are then divided into factors and each pair of factors is multiplied by the same number to find the gears, thus:

$$\frac{6}{24} = \frac{2 \times 3}{4 \times 6} = \frac{(2 \times 20) \times (3 \times 10)}{(4 \times 20) \times (6 \times 10)} = \frac{40 \times 30}{80 \times 60}$$

The last four numbers indicate the gears which should be used. The upper two, having 40 and 30 teeth, are the driving gears and the lower two having 80 and 60 teeth, are the driven gears. The driving gears are gear *A* on the spindle stud and gear *C* on the intermediate stud, meshing with the lead-screw gear, and the driven gears are gears *B* and *D*. It makes no difference which of the driving gears is placed on the spindle stud, or which of the driven is placed on the lead-screw. As another illustration, suppose we are to cut 1¾ thread per inch on a lathe with a lead-screw having six threads per inch, and that the numbers of teeth in the gears range from 24 to 100, increasing by 4.

$$\frac{6}{1\frac{3}{4}} = \frac{2 \times 3}{1 \times 1\frac{3}{4}} = \frac{(2 \times 36) \times (3 \times 16)}{(1 \times 36) \times (1\frac{3}{4} \times 16)} = \frac{72 \times 48}{36 \times 28}$$

The gear having 72 teeth is placed on the spindle stud *s*, the one with 48 on the intermediate stud *i*, meshing with the lead-screw gear. These two gears (72 and 48 teeth) are the driving gears. The gears with 36 and 28 teeth are placed on the lead-screw and on the intermediate stud and are the driven gears.

No. 45. Drop Forging.—Lay-out of Plant; Methods of Drop Forging; Dies.

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